Project Report for

TRAFFIC STUDIES, EVALUATIONS AND ITS PLANNING FOR LINCOLN'S ARTERIAL STREET SYSTEM 1999-2000 (PHASE II)

VOLUME I: ARTERIAL TRAFFIC FLOW AND SIGNAL TIMING ANALYSES

Submitted to

CITY OF LINCOLN, NEBRASKA
PUBLIC WORKS & UTILITIES DEPARTMENT

Submitted by

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EXECUTIVE SUMMARY

It is the goal of the City of Lincoln, Public Works and Utilities Department, Engineering Services Division, to monitor the City's main arterials over time. Approximately every three years, each arterial should be monitored to track traffic patterns, growth and operations. In Fall 2000, the City contracted The Schemmer Associates Inc. to conduct an analysis and study of traffic conditions on six arterial corridors to use as a framework for future arterial evaluations. Along these six corridors, travel time and intersection delay studies were conducted with the goal of improving traffic operations through modified signal timings, rather than by widening City streets or other physical roadway improvements.

This report summarizes four tasks conducted as part of this project. These tasks include:

1. Conducting "before" and "after" travel time and intersection delay studies along six study corridors, including:

   North 27th Street ("O" Street – Interstate 80)
   North 48th Street ("O" Street – Superior Street)
   North 70th Street ("O" Street – Havelock Avenue)
   Nebraska Highway 2 (Old Cheney Road – Van Dorn Street)
   Pioneers Boulevard (56th Street – 33rd Street)
   Vine Street (70th Street – 14th Street)

2. Conducting general data collection activities, including 6-hour turning movement counts at 70 signalized intersections and 48-hour mechanical ("tube") counts at 50 locations.

3. Performing signal timing optimization and coordination analysis for the six study corridors.

4. Evaluating signal operation opportunities during low-volume, off-peak time periods along the North 27th Street and Nebraska Highway 2 corridors.

5. Performing an assessment of the City of Lincoln's existing communication network for traffic control and refined the City's future communication network needs for traffic control.

6. Identifying the City of Lincoln's Intelligent Transportation Systems (ITS) User Needs.

Summaries of tasks 5 and 6 are provided in Volume II of this report. Volume II was submitted separately from Volume I.

As part of Task 1, "before" and "after" travel time studies were conducted along six arterial corridors and intersection delay studies at 34 signalized intersections associated with the six study corridors. "After" studies were performed to quantify changes in traffic operations resulting from signal timing changes performed as part of Task 3. Results of these studies indicate that through optimizing signal timings, only incremental changes can be made to the existing traffic signal timing plans. However, even minor improvements in signal timings can be beneficial to traffic operations along arterial corridors and at individual intersections.

Through activities performed as part of Task 4, signal operation opportunities during low-volume, off-peak time periods were evaluated, specifically along the North 27th Street and Nebraska Highway 2 corridors. Specifically, the use of flashing signal operation was investigated. Due to the possibility of increased accidents as a result of driver and pedestrian confusion, flashing operation is not recommended for the City of Lincoln. Rather, if the intersection is semi- or fully-actuated, the intersection should be set to operate with "free" operation.

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This report is a tool to be used internally by the City of Lincoln, Public Works and Utilities Department to continuously monitor traffic flow along arterial streets and make signal timing adjustments necessary to accommodate changes in traffic volumes. The objectives of the signal timing adjustments are to maximize the progression of vehicles along the arterial (reduce travel time) and optimize individual intersection operations (minimize delay). However, achieving both objectives simultaneously may not always be possible. This report incorporates the traffic monitoring methodology "average speed" as identified by the City's Congestion Management Task Force in 1997. Although this report does make reference to using average speed as the "trigger" for identifying the need for additional study of an arterial, it does not dictate if, in fact, the "trigger" speed has been reached, nor is it the only deciding factor in determining the need for roadway improvements.

1.0 INTRODUCTION

It is the goal of the City of Lincoln, Public Works and Utilities Department, Engineering Services Division, to monitor the City's main arterials over time. Approximately every three years, each arterial should be monitored to track traffic patterns, growth and operations. In Spring 1998, the City contracted The Schemmer Associates Inc. (TSA) to conduct an analysis and study of traffic conditions on ten arterial corridors to use as a framework for future arterial evaluations. Along these ten corridors, travel time and intersection delay studies were conducted with the goal of improving traffic operations (decreasing delay and travel time; increasing average speed) through modified signal timings, rather than by widening City streets or other physical roadway improvements. The ten corridors included in this contract included:

- South 27th Street (Old Cheney Road to "O" Street)
- North/South 33rd Street ("A" Street to Cornhusker Highway)
- South 40th Street (Duxhall Drive to Randolph Street)
- South 48th Street (Nebraska Highway 2 to "O" Street)
- Superior Street (Cornhusker Highway to I-180)
- Cornhusker Highway (Superior Street/Havelock Avenue to 11th Street)
- Holdrege Street (70th Street to 27th Street)
- Randolph Street (56th Street/Cotner Boulevard to Capitol Parkway)
- South Street (56th Street to 9th Street)
- Old Cheney Road (Nebraska Highway 2 to Warlick Boulevard)

As a result of studies being performed as part of the East "O" Street Project (1999), an 11th corridor was added to this list:

- 56th Street (Nebraska Highway 2 to "R" Street)

All of the corridors listed above, which were studied during the Spring of 1998 and Fall of 1999, are shown in Figure 1.

In April 2000, TSA was contracted to conduct studies along six additional corridors as listed below:

- North 27th Street ("O" Street to I-80)
- North 48th Street ("O" Street to Superior Street)
- North 70th Street ("O" Street to Havelock Avenue)
- Nebraska Highway 2 (Old Cheney Road to Van Dorn Street)
- Pioneers Boulevard (56th Street to 33rd Street)
- Vine Street (70th Street to 14th Street)

These corridors, which were studied in the Spring and Fall of 2000, are shown in Figure 2.

FIGURE 1: 1998-1999 TRAVEL TIME STUDY CORRIDORS

FIGURE 2: 2000 TRAVEL TIME STUDY CORRIDORS

Tasks performed as part of this project include:

1) Conducting "before" and "after" travel time studies along six arterial corridors and intersection delay studies at 34 locations. The objective of this task was to perform traffic engineering studies to quantify changes in traffic operations resulting from signal timing modifications. As described previously in this section, this task is also used to monitor the City's main arterials to track traffic patterns, growth and operations over time.

2) Conducting general data collection activities, including 6-hour turning movement counts at 70 signalized intersections and 48-hour mechanical ("tube") counts at 50 locations. The objective of this task was to collect traffic volume data, which is the basis of all traffic engineering studies and evaluations, for general use by City staff and others.

3) Performing signal timing optimization and coordination analysis for these six corridors. The objective of this task was to provide a coordinated traffic signal system to reduce vehicle delays not only along the specified corridors, but also at the intersecting cross-street approaches.

4) Evaluating signal operation opportunities during low-volume, off-peak time periods along the North 27th Street and Nebraska Highway 2 corridors. The objective of this task was to research and investigate alternative modes of traffic signal operation during low-volume, off-peak time periods, such as late-night hours.

5) Performing an assessment of the City of Lincoln's existing communication network for traffic control and refined the City's future communication network needs for traffic control. The objective of this task was to identify high-level communication requirements, including discussions with various communication providers, and the development of techniques and approaches for the deployment of the overall City of Lincoln ITS communication network.

6) Identifying the City of Lincoln's Intelligent Transportation Systems (ITS) User Needs. The development of the User Needs will set the stage for the City's future ITS studies and can be used at a later time in developing an implementation plan for ITS in the City of Lincoln.

   Summaries of tasks 5 and 6 are provided in Volume II of this report. Volume II was submitted separately from Volume I.

All data collection activities, methodologies and calculations related to the travel time and intersection delay studies were performed based on nationally accepted engineering practices outlined by the Institute of Transportation Engineers (ITE).

2.0 SUMMARY OF "BEFORE" AND "AFTER" STUDIES

In 1995, the Congestion Management Task Force recommended "average speed" to be the measure-of-effectiveness in evaluating the operational performance of arterial streets. Therefore, the recommended signal timing modifications (Task 3, Section 4.0) were evaluated by conducting travel time studies along each of the six corridors *before* signal timing improvements were made, and again *after* implementation of the new signal timings. Also, "before" and "after" intersection delay studies were conducted at 34 signalized intersections to measure the amount of stopped-delay experienced by vehicles at these individual intersections.

The stated goal of the City is to have its streets operate at or above LOS 'C', which describes stable operations. However, ability to maneuver and change lanes in mid-block locations may be more restricted. "The key action by the Task Force was the adoption of an average speed of 18 mph as the 'trigger' for initiating a study that could result in street improvement projects. An average speed of 16 mph was adopted as the 'trigger' at which the study recommendations would be implemented."[1] These 'trigger speeds' were established for arterials with a typical free flow speed of 35 mph. Figure 3 illustrates the model of the trigger mechanism discussed, using average speed as the basic measure of congestion, for arterials with typical free flow speeds of 35 mph. This figure also reveals the relationship between average speed on the study segments and the corresponding level-of-service (LOS).

Based on the 1994 and 2000 Highway Capacity Manuals (HCM), 18 mph represents the threshold between LOS 'C' and 'D' for arterials with 35 mph free flow speeds. According to Exhibit 15-2 of the 2000 HCM, also shown as Table 1, the corresponding 'trigger speeds' for an arterial with a typical free flow speed of 40 mph are 22 mph and 19.5 mph. The corresponding 'trigger speeds' for an arterial with a typical free flow speed of 50 mph are 27 mph and 24 mph.

Table 1: Urban Street LOS by Class

Urban Street Class	I	II	III	IV
Range of free-flow speeds (FFS)	55 to 45 mph	45 to 35 mph	35 to 30 mph	35 to 25 mph
Typical FFS	50 mph	40 mph	35 mph	30 mph
LOS	Average Travel Speed (mph)			
A	> 42	> 35	> 30	> 25
B	> 34-42	> 28-35	> 24-30	> 19-25
C	> 27-34	> 22-28	> 18-24	> 13-19
D	> 21-27	> 17-22	> 14-18	> 9-13
E	> 16-21	> 13-17	> 10-14	> 7-9
F	≤ 16	≤ 13	≤ 10	≤ 7

[1] The Mayor's Congestion Management Task Force, "Final Report for the City of Lincoln, Nebraska", October 10, 1996

FIGURE 3: USE OF AVERAGE SPEED AS TRIGGER MECHANISM

2.1 Travel Time Studies

Travel time is the elapsed time it takes for a vehicle to traverse a given segment of a street. Travel time studies provide the necessary data to determine the average travel time. Combined with the length of the corridor under study, this data can be used to produce average travel speed. Travel time and delay are two of the principal measures of roadway system performance used by traffic engineers, planners and analysts. Since vehicle speed is directly related to travel time and delay, it is also an appropriate measure-of-performance to evaluate traffic systems.

Travel time studies were conducted noting the sources and amount of delay occurring within the study corridor. Each of the study corridors were divided into several "links", which were defined by signalized intersections or signalized pedestrian crosswalks. The boundaries of these links were identified as the far-side curb of the intersection, or just beyond each of the signalized locations. Therefore, delay for a particular intersection was included in the total delay of the link ending at that intersection.

The Institute of Transportation Engineers' (ITE) *Manual of Traffic Engineering Studies* recommends that the comparison of "before" and "after" studies have a range of permitted error of ± 1 to ± 3 mph. ITE also recommends using the average range in running speed (i.e., the average speed of a vehicle traveling over a predetermined speed) to determine the minimum number of individual runs necessary to achieve an acceptable range of error. This accepted methodology predicts that with eight (8) separate runs, and a maximum average range in running speed of 5.0 mph, a confidence level of 95% is achieved, with a permitted error of ± 1 mph. Therefore, a minimum of eight runs were conducted for each corridor, during each time period and in each direction for both the "before" and "after" conditions.

Travel time studies were conducted for each of the study corridors during the AM Peak (7:00-8:30 a.m.), Midday (11:00 a.m.–1:00 p.m.) and PM Peak (4:00-6:00 p.m.) time periods. In addition, all travel time studies were conducted on days that are representative of Lincoln's average traffic day. These are days with dry and clear weather conditions, all schools and universities in session and no special events (e.g., State Fair, state high school athletic tournaments, Fridays before home Nebraska football games) are taking place.

Travel time data was collected using equipment manufactured by Jamar Technologies, Inc. and connected to a 2000 Chevrolet Malibu. Using sensors attached to the vehicle's transmission, electronic pulses are converted to units of distance and sent to a hand-held electronic data collection device (TDC-8) that records the information in one-second intervals. A software package, PC-TRAVEL, was then used to analyze the data, including calculating total travel time, average speed, total delay, fuel consumption and vehicle emissions. Additional statistical computations were performed by TSA to determine standard deviations and confidence intervals.

2.1.1 Definitions of Travel Time Statistics

The following is a list of the variables, and their respective definitions, reported in the travel time study summaries (*Sections 2.1.2 – 2.1.7*):

Section Number - each travel-time corridor is divided into individual links, or sections, usually defined by a signalized intersection or pedestrian crosswalk. The *section number* is the sequential numbering of these sections.

Length - the average length, in feet, of the individual sections and the overall corridor.

Section Name - the name of the street or pedestrian crossing that defines the downstream end of the individual sections.

Average Travel Time - the average time, in seconds, elapsed while driving between two points.

Standard Deviation - (sec, mph) a measure of the variability of the travel time and average speed.

Average Stops - the average number of stops experienced by section and overall corridor. A stop is defined as a one-second interval where the speed is less than 5 feet per second and the speed was greater than 5 feet per second during the previous one-second interval. Therefore, each time the vehicle slows down and crosses the 5 feet per second threshold, a stop is counted. The vehicle must speed up faster than the threshold before another stop can be counted. When a car stops in queue, slight creeping will not be counted as multiple stops.

Average Speed - (mph) computed by dividing the length by the average travel time.

95% Confidence Interval - (mph) a measure of how well the average speed, calculated from the actual travel time runs, represents the actual average of the entire population. In other words, one can say, with 95% certainty, that the average speed of the entire driving population falls within the range defined by the sample average speed, plus/minus the 95% Confidence Interval. (See also definition for "Range of Average Speed".)

Average Speed Within This Range - (mph) the upper and lower limits for the variation in average speed.

Defined As: Upper Limit = (Average Speed + Confidence Interval)
Lower Limit = (Average Speed - Confidence Interval)

Time Duration Below (Seconds) - the three columns under this variable summarize the amount of time, in seconds, where the vehicle speed was less than or equal to 0, 7 and 28 miles per hour, respectively. These three speeds are commonly used to represent the speed below which a car is stopped, queued, and delayed on a typical urban street. Speeds above 28 miles per hour are considered "free running".

Average Delay - difference between the actual travel time and the ideal travel time.

Ideal Travel Time (Unrestricted Travel Time) - the time it would take to traverse the section/corridor at the posted speed limit.

Number of Runs - the number of times the corridor was driven in a specific direction during the noted time period.

Posted Speed Limit - the speed limit posted along the roadway. The posted speed limit is used to calculate the ideal travel time for the corridor. Since the posted speed limit can vary within a particular study corridor, the ideal travel time is computed for each individual segment of the corridor using the posted speed limit for that segment.

Fuel (gal.) - the average amount of fuel, in gallons, consumed in traversing the section/corridor. Computed using a fuel consumption model developed by the Australian Road Research Board.

HC, CO, NOx (grams) - the average amount of hydrocarbons, carbon monoxide and nitrous oxides emitted while traversing the section/corridor. Computed using the MICRO2 model developed by the Colorado Department of Transportation.

The following six sections summarize the results of the "before" and "after" travel time studies. Detailed "after" travel time summaries for each corridor, time period and direction are provided in Appendix A. Summaries of the "before" travel time studies were previously submitted as part of Phase I of this project. These summaries also provide average travel time statistics for the individual segments that comprise each of the six corridors.

2.1.2 North 27th Street ("O" Street to I-80; 5.2 miles)

Tables 2a and 2b summarize the results of the travel time studies conducted along North 27th Street. The limits of this corridor were defined by the intersection at "O" Street on the south and Interstate 80 on the north. For a majority of its length, this corridor is characterized by commercial land uses. Between Cornhusker Highway and Kensington Drive, it is further characterized by commercial "big box" type uses (e.g., Kmart, Menards, Shopko, WalMart, HyVee, Super Saver, Sam's Club). North 27th Street has a posted speed limit of 35 mph between "O" Street and Fair Street, 40 mph between Fair Street and Cornhusker Highway and 45 mph from Cornhusker Highway to Interstate 80 (I-80).

Table 2a: "Before" Travel Time Studies-North 27th Street ("O" Street to I-80)

"BEFORE"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM		Off-Peak 10:30 PM – 12:00 AM	
Date of Study Day 1: Day 2: Day 3:	Fri., 2/4/00 Thur., 2/10/00 Tue., 2/15/00		Fri., 2/4/00 Thur., 2/10/00 -		Thur., 2/10/00 Fri., 2/11/00 -		Thur., 2/10/00 Tue., 2/15/00 -	
Travel Time Statistic	NB[2]	SB[2]	NB[2]	SB[2]	**NB[1]**	SB	NB[2]	SB[2]
Average Travel Time (sec)	580.0	599.9	582.7	609.0	698.6	774.9	592.9	590.8
Standard Deviation (sec)	66.9	63.9	42.0	58.5	49.4	82.8	55.3	57.2
Average Number of Stops	2.4	3.6	2.8	4.8	5.3	6.1	3.2	3.2
Average Speed (mph)	31.9	31.2	32.0	30.7	26.8	24.2	31.2	31.6
Standard Deviation (mph)	3.9	3.2	2.3	3.0	2.0	2.6	3.2	3.3
95% Confidence Interval (mph)	2.8	2.5	1.8	2.5	1.7	2.7	2.7	2.5
Average Speeds Within This Range (mph)[3] Lower Limit: Upper Limit:	29.1 34.7	28.7 33.7	30.2 33.8	28.2 33.2	25.1 28.5	21.5 26.9	28.5 33.9	29.1 34.1
Time Duration Below: 0 mph 7 mph 28 mph	88.0 99.1 154.1	70.1 91.7 171.2	52.0 69.5 158.6	72.1 97.1 185.3	140.6 176.2 300.2	195.2 242.4 392.2	80.7 96.5 167.3	77.0 91.8 160.0
Average Delay (sec)	138.7	152.0	135.9	164.8	258.9	335.7	148.5	141.1
Number of Runs	10	9	9	8	8	6[4]	8	9
Length (feet)	27,177	27,472	27,330	27,379	27,428	27,459	27,135	27,396

[1]Bolded direction indicates the direction of traffic which is favored by signal timings.
[2]Neither direction is significantly favored by existing signal timings.
[3]Limits of the range of average speed calculated based on the 95% confidence interval.
[4]Due to equipment malfunction, only six (6) runs were conducted for this direction.

Notes: No "after" studies were performed for the off-peak time period.
Posted Speed Limit: "O" Street – Fair Street = 35 mph
Fair Street – Cornhusker Highway = 40 mph
Cornhusker Highway – I-80 = 45 mph

Ideal Travel Time = 444.2 seconds (7 minutes 24.2 seconds)

Table 2b: "After" Travel Time Studies-North 27th Street ("O" Street to I-80)

"AFTER"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM	
Date of Study Day 1: Day 2: Day 3:	Tue., 10/10/00 Wed., 10/11/00 Mon., 11/20/00		Tue., 10/10/00 Wed., 10/11/00 -		Tue., 10/10/00 Wed., 10/11/00 -	
Travel Time Statistic	NB[2]	SB[2]	NB[2]	SB2	**NB[1]**	SB
Average Travel Time (sec)	562.8	593.8	590.3	622.0	634.5	718.3
Standard Deviation (sec)	56.8	35.8	31.8	36.8	53.4	58.8
Average Number of Stops	1.6	3.4	2.8	4.5	3.7	5.7
Average Speed (mph)	32.9	31.3	31.4	30.1	29.1	26.0
Standard Deviation (mph)	3.1	1.9	1.7	1.8	2.5	2.1
95% Confidence Interval (mph)	2.2	1.5	1.4	1.4	2.1	1.8
Average Speeds Within This Range (mph)[3] Lower Limit: Upper Limit:	30.7 35.1	29.8 32.8	30.0 32.8	28.7 31.5	27.0 31.2	24.2 27.8
Time Duration Below: 0 mph 7 mph 28 mph	82.1 89.5 136.3	77.0 92.9 179.3	78.4 96.0 173.6	78.5 102.5 208.0	112.7 132.8 224.7	138.7 178.1 328.1
Average Delay (sec)	117.2	145.8	148.8	172.5	195.0	271.5
Number of Runs	10	9	8	9	8	8
Length (feet)	27,125	27,230	27,177	27,491	27,102	27,345

From the results of the "after" studies and from the standpoint of an overall corridor, average speeds along North 27th Street exceed 25 mph. During the AM Peak and Midday time periods, average speeds greater than 30 mph were observed in both directions. In general, increases in average speeds were observed between the "before" and "after" travel time studies. Although deviations in the average speeds do exist, as represented by the upper and lower limits of the confidence interval, increases in average speed up to 2.3 mph were experienced. Decreases in average speed, less than one mile per hour in both directions, were experienced during the Midday time period.

Table 2a also summarizes the results of "before" travel time studies that were conducted during a low-volume, off-peak time period (10:30 p.m.–12:00 a.m.). These studies were conducted in association with the efforts of Task 4 (Section 5.0). Since no signal timing adjustments were made, "after" studies were not conducted.

As discussed in Section 2.0, different 'trigger speeds' are in effect for corridors with different free flow speeds. As already mentioned in this section, the North 27th Street corridor is composed of groups of links with different posted speed limits, thus different free flow speeds. Individual links along the North 27th Street corridor that experienced "after" average speeds less than the corresponding 'trigger speed' for the corridor are summarized in Table 3.

Table 3

Time Period	Direction	Link	Average Speed (mph)	'Trigger Speed' (mph)
AM Peak	Northbound	"Y" Street – Holdrege Street	12.9	18
	Southbound	Ticonderoga Drive – Superior Street	15.7	22
		Kmart Drive – Cornhusker Highway	7.7	22
		"P" Street – "O" Street	10.9	18
Midday	Northbound	"Y" Street – Holdrege Street	14.4	18
	Southbound	Ticonderoga Drive – Superior Street	14.6	22
		Kmart Drive – Cornhusker Highway	10.6	22
		"P" Street – "O" Street	8.2	18
PM Peak	Northbound	"Y" Street – Holdrege Street	12.6	18
		Fairfield Street – Superior Street	21.2	22
	Southbound	Ticonderoga Drive – Superior Street	7.2	22
		Kmart Drive – Cornhusker Highway	6.4	22
		Fair Street – Holdrege Street	15.2	18
		"P" Street – "O" Street	8.8	18

Note: Posted Speed Limit: "O" Street – Fair Street = 35 mph
Fair Street – Cornhusker Highway = 40 mph
Cornhusker Highway – I-80 = 45 mph

As expected, the segments that experienced low average speeds are those links that are defined by a major intersection at the downstream end of the segment. At these intersections, approaches on the travel time corridor and the cross-street approaches are characterized by high traffic volumes. In addition to the high traffic volumes in all directions competing for traffic signal green time, these volumes also dictate the need for additional signal phases, resulting in high intersection delay and low travel speeds. Section 2.2 will discuss operations at these intersections in further detail.

During the AM Peak time period, average speeds between "Y" Street and Holdrege Street are further affected by school speed zone flashing beacons, which reduce the speed limit to 25 mph when activated.

From the detailed link statistics, as provided in Appendix A, additional conclusions can be drawn for operations along the North 27th Street corridor. For instance, in the southbound direction during the Midday time period, the link between "P" Street and "O" Street experienced an average of 1.1 stops. This indicates that on at least one occasion, the study vehicle waited through two signal cycles at the intersection of 27th/"O" Streets before continuing southbound. Operations similar to this occur in the southbound direction at the intersections of 27th/Superior Streets and 27th Street/Cornhusker Highway during the PM Peak time period.

Average speeds of the entire corridor do not accurately reflect average speeds through the heavily commercialized portions of the corridor, since north of Kensington Drive, the speed limit is posted at 45 mph and traffic signals were not in place at the time of the travel time studies. Evaluating the North 27th Street *sub-corridor* from "O" Street to Kensington Drive results in average travel times and average speeds summarized in Tables 4a and 4b.

Table 4a: North 27th Street ("O" Street – Kensington Drive) – "Before" Studies

Travel Time Statistic	AM Peak		Midday		PM Peak	
	NB	SB	NB	SB	NB	SB
Average Travel Time (sec)	442.3	454.4	437.3	465.0	560.9	636.5
Average Speed (mph)	27.2	26.5	27.5	25.9	21.5	18.9
Length (feet)	17,670	17,660	17,640	17,685	17,653	17,662

Table 4b: North 27th Street ("O" Street – Kensington Drive) – "After" Studies

Travel Time Statistic	AM Peak		Midday		PM Peak	
	NB	SB	NB	SB	NB	SB
Average Travel Time (sec)	420.8	449.4	452.0	473.1	496.8	573.4
Average Speed (mph)	28.7	26.8	26.7	25.5	24.2	21.0
Length (feet)	17,687	17,668	17,671	17,676	17,655	17,671

Comparison of the average speeds of Table 1 ("O" Street to I-80) and Table 4b ("O" Street to Kensington Drive), the 1.8 miles (approximate) of roadway, between Kensington Drive and Interstate 80, without traffic signals, and with a posted speed limit of 45 mph, inflates the average speed of the entire corridor as much as 5.0 mph. However, as the north end of the North 27th Street corridor continues to develop, and traffic signals are constructed, average speeds in this area will decrease as well.

2.1.3 North 48th Street ("O" Street to Superior Street; 3.0 miles)

Tables 5a and 5b summarize the results of the travel time studies conducted along North 48th Street. The limits of this corridor were defined by the intersection at "O" Street on the south and Superior Street on the north. For the majority of its length, this corridor is characterized by commercial land uses. Between "O" Street and Vine Street, it is further characterized by commercial "big box" type uses (e.g., Super Saver, Target, Best Buy). 48th Street is posted with speed limits of 35 mph south of Leighton Avenue and north of Adams Street and 25 mph between Leighton Avenue and Adams Street.

From the results of the "after" studies and from the standpoint of an overall corridor, average speeds along North 48th Street during the AM Peak and Midday time periods exceed 20 mph. Between the "before" and "after" studies, decreases in average speed were observed in the southbound direction during both of these time periods. From the results of the "before" studies, average speeds during the PM Peak time period were observed to be 19.0 mph and 16.7 mph in the northbound and southbound directions, respectively. Results from the "after" studies indicate that average speeds in the northbound direction increased to 22.8 mph while southbound average speeds remained relatively unchanged at 17.3 mph. Individual links that experienced average speeds less than 18 mph during the "after" studies are summarized in Table 6.

Table 5a: "Before" Travel Time Studies-North 48th Street ("O" Street-Superior Street)

"BEFORE"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM	
Date of Study						
Day 1:	Fri., 1/28/00		Wed., 2/9/00		Wed., 2/9/00	
Day 2:	Mon., 1/31/00		Tue., 2/15/00		Mon., 2/14/00	
Travel Time Statistic	**NB**[1]	SB	NB[2]	SB[2]	**NB**[1]	SB
Average Travel Time (sec)	406.2	456.8	413.2	460.5	567.6	643.7
Standard Deviation (sec)	9.8	54.5	30.0	61.1	46.3	58.2
Average Number of Stops	2.4	4.1	2.6	3.7	6.0	7.3
Average Speed (mph)	26.5	23.6	26.1	23.4	19.0	16.7
Standard Deviation (mph)	0.6	2.8	2.2	3.2	1.5	1.7
95% Confidence Interval (mph)	0.6	2.3	1.7	2.2	1.2	1.4
Average Speeds Within This Range (mph)[3]						
Lower Limit:	25.9	21.3	24.4	21.3	17.8	15.3
Upper Limit:	27.1	25.9	27.8	25.6	20.2	18.1
Time Duration Below:						
0 mph	32.3	67.5	59.7	78.1	151.3	192.9
7 mph	46.1	90.4	74.6	98.3	184.4	240.4
28 mph	162.9	224.7	156.3	210.2	348.2	450.2
Average Delay (sec)	83.9	133.1	90.3	134.1	238.9	315.3
Number of Runs	6[4]	8	9	11	9	8
Length (feet)	15,807	15,800	15,822	15,811	15,818	15,804

[1]Bolded direction indicates the direction of traffic which is favored by signal timings.
[2]Neither direction is significantly favored by existing signal timings.
[3]Limits of the range of average speed calculated based on the 95% confidence interval.
[4]Due to equipment malfunction, only six (6) runs were conducted for this direction.

Note: Posted Speed Limit: "O" Street – Leighton Ave. = 35 mph
Leighton Ave. – Adams Street = 25 mph
Adams Street – Superior Street = 35 mph
Ideal Travel Time = 325.4 seconds (5 minutes 25.4 seconds)

Table 5b: "After" Travel Time Studies-North 48th Street ("O" Street-Superior St.)

"AFTER"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM	
Date of Study						
Day 1:	Thur., 10/5/00		Thur., 10/5/00		Thur., 10/5/00	
Day 2:	Fri., 10/6/00		Fri., 10/6/00		Fri., 10/6/00	
Travel Time Statistic	**NB**[1]	SB	NB[2]	SB[2]	**NB**[1]	SB
Average Travel Time (sec)	412.2	514.8	404.4	482.0	472.8	623.6
Standard Deviation (sec)	19.1	126.1	39.9	61.6	49.4	87.3
Average Number of Stops	2.9	4.4	1.8	3.6	4.5	6.4
Average Speed (mph)	26.2	21.0	26.7	22.4	22.8	17.3
Standard Deviation (mph)	1.2	4.3	3.0	2.5	2.4	2.5
95% Confidence Interval (mph)	1.0	3.6	2.1	1.9	2.0	1.9
Average Speeds Within This Range (mph)[3]						
Lower Limit:	25.2	17.4	24.6	20.5	20.8	15.4
Upper Limit:	27.2	24.6	28.8	24.3	24.8	19.2
Time Duration Below:						
0 mph	27.5	107.9	41.0	92.1	69.9	198.1
7 mph	45.6	143.0	50.4	113.3	96.7	236.1
28 mph	178.1	280.6	151.7	241.7	235.6	412.1
Average Delay (sec)	86.3	188.6	79.5	154.4	143.8	295.5
Number of Runs	8	8	10	9	8	9
Length (feet)	15,839	15,837	15,837	15,817	15,835	15,828

Table 6

Time Period	Direction	Link	Average Speed (mph)
AM Peak	Northbound	Huntington Ave. Ped Signal – St. Paul Street Fremont Street – Cornhusker Highway	15.1 17.7
	Southbound	Superior Street – Cornhusker Highway	9.6
Midday	Northbound	"R" Street – Vine Street	12.8
	Southbound	Vine Street – "R" Street "R" Street – "O" Street	16.8 11.7
PM Peak	Northbound	Orchard St. Ped Signal – Holdrege Street Huntington Ave. Ped Signal – St. Paul Street Fremont Street – Cornhusker Highway	13.1 18.0 14.4
	Southbound	Superior Street – Cornhusker Highway Huntington Ave. Ped Signal – Leighton Avenue Leighton Avenue- Holdrege Street "R" Street – "O" Street	14.9 10.2 14.6 8.1

Note: Posted Speed Limit: "O" Street – Leighton Ave. = 35 mph
Leighton Ave. – Adams Street = 25 mph
Adams Street – Superior Street = 35 mph

Similar to the 27th Street corridor, many of the segments that experienced low average speeds are links that are defined by a major intersection at the downstream end of their segment. The exceptions to this are the northbound and southbound links bounded by St. Paul Street at their downstream end. Probable reasons for low average speeds on these links are twofold; first, the posted speed limit between Leighton Avenue and Adams Street is 25 mph; second, left-turn lanes on 48th Street at St. Paul Street are not provided. Therefore, vehicles must perform their left-turn maneuver from the inside through lane on 48th Street. This causes additional through vehicles to 'stack' behind the left-turning vehicles and reduces the through capacity to a single lane. Section 2.2 will discuss operations at these intersections in further detail.

From the detailed link statistics, as provided in Appendix A, additional conclusions can be drawn for operations along the North 48th Street corridor. In the southbound direction during the AM Peak time period, the link between Superior Street and Cornhusker Highway experienced an average of 2.0 stops. This indicates that on several occasions, the study vehicle waited through two signal cycles at the intersection of 48th Street/Cornhusker Highway before continuing southbound. Operations similar to this occur during the PM Peak in the northbound direction at the intersection of 48th/Fremont Streets and in the southbound direction at the intersections of 48th Street/Cornhusker Highway, 48th/Holdrege Streets and 48th/"O" Streets.

2.1.4 North 70th Street ("O" Street to Havelock Avenue; 3.0 miles)

Tables 7a and 7b summarize the results of the travel time studies conducted along North 70th Street. The limits of this corridor were defined by the intersection at "O" Street on the south and Havelock Avenue on the north. The majority of this corridor is characterized by residential type land uses, with additional commercial uses near the intersections of "O" Street, Vine Street, Adams Street and Havelock Avenue. 70th Street has a posted speed limit of 35 mph.

From the results of the "after" studies and from the standpoint of an overall corridor, average speeds along North 70th Street are near or exceed 25 mph.

Table 7a: "Before" Travel Time Studies-North 70th Street ("O" Street-Havelock Avenue)

"BEFORE"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM	
Date of Study Day 1: Day 2:	Wed., 1/26/00 Thur., 1/27/00		Wed., 1/26/00 Thur., 1/27/00		Wed., 1/26/00 Thur., 1/27/00	
Travel Time Statistic	**NB**[1]	SB	NB[2]	SB[2]	**NB**[1]	SB
Average Travel Time (sec)	404.8	437.6	374.3	402.2	382.1	458.2
Standard Deviation (sec)	28.1	58.5	37.0	50.3	19.5	39.0
Average Number of Stops	3.8	3.6	2.4	2.6	2.1	3.5
Average Speed (mph)	26.5	24.6	28.7	26.7	28.1	23.5
Standard Deviation (mph)	1.9	3.8	3.2	3.2	1.6	1.9
95% Confidence Interval (mph)	1.6	3.2	2.3	2.3	1.2	1.4
Average Speeds Within This Range (mph)[3] Lower Limit: Upper Limit:	24.9 28.1	21.4 27.8	26.4 31.0	24.4 29.0	26.9 29.3	22.1 24.9
Time Duration Below: 0 mph 7 mph 28 mph	40.4 58.0 146.3	71.6 90.3 174.7	21.2 37.3 110.1	40.4 58.4 133.1	20.3 32.9 124.2	81.5 103.2 201.8
Average Delay (sec)	98.0	130.1	67.6	94.9	75.4	150.6
Number of Runs	8	8	10	10	9	10
Length (feet)	15,749	15,784	15,744	15,773	15,743	15,789

[1]Bolded direction indicates the direction of traffic which is favored by signal timings.
[2]Neither direction is significantly favored by existing signal timings.
[3]Limits of the range of average speed calculated based on the 95% confidence interval.

Note: Posted Speed Limit: "O" Street – Havelock Avenue = 35 mph
Ideal Travel Time = 307.1 seconds (5 minutes 7.1 seconds)

Table 7b: "After" Travel Time Studies-North 70th Street ("O" Street-Havelock Ave.)

"AFTER"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM	
Date of Study Day 1: Day 2:	Fri., 2/23/01 Mon., 3/5/01		Fri., 2/23/01 Mon., 3/5/01		Mon., 2/26/01 Mon., 3/5/01	
Travel Time Statistic	**NB**[1]	SB	NB[2]	SB[2]	**NB**[1]	SB
Average Travel Time (sec)	369.3	422.3	364.1	397.0	414.7	432.6
Standard Deviation (sec)	26.9	57.1	27.5	33.3	31.9	33.2
Average Number of Stops	1.7	3.0	1.6	2.6	3.2	3.3
Average Speed (mph)	29.2	25.5	29.5	27.1	25.9	24.9
Standard Deviation (mph)	2.1	3.6	2.2	2.3	2.1	2.0
95% Confidence Interval (mph)	1.6	2.8	1.4	1.5	1.8	1.4
Average Speeds Within This Range (mph)[3] Lower Limit: Upper Limit:	27.6 30.8	22.7 28.3	28.1 30.9	25.6 28.6	24.1 27.7	23.5 26.3
Time Duration Below: 0 mph 7 mph 28 mph	15.4 27.6 99.9	46.8 70.4 162.9	9.3 21.3 98.2	35.1 55.7 128.7	26.3 48.6 159.6	52.1 77.7 170.8
Average Delay (sec)	61.6	114.3	57.1	89.3	107.4	124.7
Number of Runs	9	9	12	12	8	10
Length (feet)	15,796	15,810	15,761	15,796	15,776	15,806

In general, increases in average speeds were observed between the "before" and "after" travel time studies. Although deviations in the average speeds do exist, as represented by the upper and lower limits of the confidence interval, increases in average speed were as high as 2.7 mph. A decrease in average speed of 2.2 mph was observed in the northbound direction during the PM Peak time period. Individual links that experienced average speeds less than 18 mph during the "after" studies are summarized in Table 8.

Table 8

Time Period	Direction	Link	Average Speed (mph)
AM Peak	Northbound	None	
	Southbound	MOPAC Trail Crossing – "O" Street	9.4
Midday	Northbound	None	
	Southbound	MOPAC Trail Crossing – "O" Street	11.8
PM Peak	Northbound	None	
	Southbound	MOPAC Trail Crossing – "O" Street	8.8

Note: Posted Speed Limit: "O" Street – Havelock Avenue = 35 mph

As expected, high intersection delays at the intersection of 70th/"O" Streets result in low travel speeds in the southbound direction. All other links were found to operate with average speeds above 18 mph.

2.1.5 Nebraska Highway 2 (Old Cheney Road to Van Dorn Street; 4.5 miles)

Tables 9a and 9b summarize the results of the travel time studies conducted along Nebraska Highway 2. The limits of this corridor were defined by the intersection at Old Cheney Road on the east and the intersections along Van Dorn Street at 9th and 10th Streets on the west. The majority of this corridor is characterized by commercial land uses. This corridor also has a posted speed limit of 45 mph.

The results of the "before" and "after" studies along Highway 2 indicate that decreases in average speeds were observed during all three time periods. Although deviations in the average speed do exist, as shown by the upper and lower limits of the confidence interval, decreases in average speed up to 1.9 mph were observed. General increases in average speed were observed in the westbound direction of the Midday time period and the eastbound direction of the PM Peak time period.

Table 9a also summarizes the results of "before" travel time studies that were conducted during a low-volume, off-peak time period (10:30 p.m. – 12:00 a.m.). These studies were conducted in association with the efforts of Task 4 (Section 5.0). Since no signal timing adjustments were made, "after" studies were not conducted.

Table 9a: "Before" Travel Time Studies-Nebraska Highway 2 (Old Cheney Road-Van Dorn Street)

"BEFORE"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM		Off-Peak 10:30 PM – 12:00 AM	
Date of Study Day 1: Day 2:	Mon., 1/24/00 Tue., 1/25/00		Mon., 1/24/00 Tue., 1/25/00		Mon., 1/24/00 Tue., 1/25/00		Mon., 2/21/00 Tue., 2/22/00	
Travel Time Statistic	EB	**WB**[1]	EB[2]	WB[2]	**EB**[1]	WB	EB[2]	WB[2]
Average Travel Time (sec)	501.0	436.2	419.5	429.8	469.1	518.1	429.6	415.7
Standard Deviation (sec)	91.5	49.1	24.7	30.6	48.0	16.2	39.5	20.5
Average Number of Stops	3.3	1.5	1.3	1.6	2.5	3.8	2.6	2.0
Average Speed (mph)	32.1	36.7	38.3	37.2	34.3	30.8	37.5	38.5
Standard Deviation (mph)	6.7	4.0	2.4	2.8	3.3	1.0	3.6	2.0
95% Confidence Interval (mph)	5.6	3.3	2.0	2.0	2.5	0.8	2.6	1.4
Average Speeds Within This Range (mph)[3] Lower Limit: Upper Limit:	26.5 37.7	33.4 40.0	36.3 40.3	35.2 39.2	31.8 36.8	30.0 31.6	34.9 40.1	37.1 39.9
Time Duration Below: 0 mph 7 mph 28 mph	73.3 91.1 152.1	29.4 38.1 78.0	17.6 28.0 64.8	14.6 27.5 79.5	43.8 58.8 107.5	89.5 109.5 173.8	28.6 40.3 77.4	19.3 30.3 66.9
Average Delay (sec)	143.1	80.7	62.3	76.4	111.6	163.0	72.3	61.3
Number of Runs	8	8	8	10	9	9	10	10
Length (feet)	23,620	23,460	23,573	23,457	23,593	23,434	23,654	23,492

[1]Bolded direction indicates the direction of traffic which is favored by signal timings.
[2]Neither direction is significantly favored by existing signal timings.
[3]Limits of the range of average speed calculated based on the 95% confidence interval.

Notes: No "after" studies were performed for the off-peak time period.
Posted Speed Limit: Van Dorn Street – Arapahoe Street = 40 mph
Arapahoe Street – Old Cheney Road = 45 mph
Ideal Travel Time = 356.0 seconds (5 minutes 56.0 seconds)

Table 9b: "After" Travel Time Studies-Neb. Hwy 2 (Old Cheney Rd.-Van Dorn St.)

"AFTER"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM	
Date of Study Day 1: Day 2: Day 3: Day 4:	Wed., 10/18/00 Thur., 10/19/00 Mon., 11/13/00 Tue., 11/14/00		Wed., 10/18/00 Thur., 10/19/00 - -		Wed., 10/18/00 Thur., 10/19/00 - -	
Travel Time Statistic	EB	**WB**[1]	EB[2]	WB[2]	**EB**[1]	WB
Average Travel Time (sec)	531.2	438.1	442.8	418.8	465.1	534.8
Standard Deviation (sec)	52.2	41.8	40.1	47.8	44.9	41.2
Average Number of Stops	5.4	1.8	1.6	1.6	1.3	4.6
Average Speed (mph)	30.4	36.6	36.4	38.3	34.7	29.9
Standard Deviation (mph)	3.3	3.5	3.2	4.0	3.1	2.3
95% Confidence Interval (mph)	2.5	2.7	2.3	3.1	2.2	1.9
Average Speeds Within This Range (mph)[3] Lower Limit: Upper Limit:	27.9 32.9	33.9 39.3	34.1 38.7	35.2 41.4	32.5 36.9	28.0 31.8
Time Duration Below: 0 mph 7 mph 28 mph	79.2 104.5 180.8	26.2 36.5 78.9	32.8 43.2 90.8	21.6 30.0 62.7	56.2 65.1 105.9	95.3 123.3 190.3
Average Delay (sec)	172.6	82.6	84.3	63.7	106.6	179.2
Number of Runs	9	9	10	9	10	8
Length (feet)	23,667	23,504	23,660	23,505	23,663	23,472

Individual links that experienced average speeds less than 27 mph during the "after" studies are summarized in Table 10.

Table 10

Time Period	Direction	Link	Average Speed (mph)
AM Peak	Eastbound	Pioneers Boulevard – 14th Street Southwood Drive – 27th Street 48th Street – 56th Street	17.0 18.5 26.4
	Westbound	Old Cheney Road – 56th Street	24.4
Midday	Eastbound	Pioneers Boulevard – 14th Street Southwood Drive – 27th Street	16.4 25.2
	Westbound	None	
PM Peak	Eastbound	Pioneers Boulevard – 14th Street	9.9
	Westbound	Old Cheney Road – 56th Street 33rd Street – 27th Street Southwood Drive – 14th Street	23.9 22.4 22.7

Note: Posted Speed Limit: Van Dorn Street – Arapahoe Street = 40 mph
Arapahoe Street – Old Cheney Road = 45 mph

Segments that experienced low average speeds along Highway 2 are those links that are defined by a major intersection at their downstream end. As mentioned previously, at these intersections, approaches on the travel time corridor and the cross-street approaches are characterized by high traffic volumes. In addition to the high traffic volumes competing for traffic signal green time, these volumes also dictate the need for additional signal phases, resulting in high intersection delay and low travel speeds. Section 2.2 will discuss operations at these intersections in further detail.

From the detailed link statistics, as provided in Appendix A, additional conclusions can be drawn for operations along the Nebraska Highway 2 corridor. In the eastbound direction during the AM Peak time period, the link between 48th Street and 56th Street experienced an average of 1.1 stops. This indicates that on at least one occasion, the study vehicle waited through two signal cycles at the intersection of 56th Street/Highway 2 before continuing eastbound. Operations similar to this occur during the PM Peak in the westbound direction at the intersection of 27th Street/Highway 2, where on average, 1.3 stops were experienced on this link.

2.1.6 Pioneers Boulevard (56th Street to 33rd Street; 1.5 miles)

Tables 11a and 11b summarize the results of the travel time studies conducted along Pioneers Boulevard. The limits of this corridor were defined by the intersection at 56th Street on the east and 33rd Street on the west. The majority of this corridor is characterized by residential type land uses, with additional commercial uses near the intersections of 33rd Street and 48th Street. Pioneers Boulevard is posted with a speed limit of 35 mph.

Table 11a: "Before" Travel Time Studies-Pioneers Boulevard (56th Street-33rd Street)

"BEFORE"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM	
Date of Study Day 1: Day 2:	Wed., 2/16/00 Thur., 2/17/00		Wed., 2/16/00 Tue., 2/22/00		Wed., 2/16/00 Thur., 2/17/00	
Travel Time Statistic	EB	**WB**[1]	EB[2]	WB[2]	EB	**WB**[1]
Average Travel Time (sec)	231.0	190.7	213.8	184.4	267.1	206.9
Standard Deviation (sec)	24.3	34.2	18.5	26.1	37.6	25.6
Average Number of Stops	2.2	1.1	1.7	1.2	2.7	2.1
Average Speed (mph)	23.3	28.1	25.2	29.0	20.1	25.9
Standard Deviation (mph)	2.6	4.5	2.3	3.9	2.9	3.6
95% Confidence Interval (mph)	1.7	2.9	1.2	1.9	1.6	2.0
Average Speeds Within This Range (mph)[3] Lower Limit: Upper Limit:	21.6 25.0	25.2 31.0	24.0 26.4	27.1 30.9	18.5 21.7	23.9 27.9
Time Duration Below: 0 mph 7 mph 28 mph	39.1 50.8 107.1	10.8 19.0 62.2	30.1 39.6 81.6	12.7 19.1 50.9	68.0 84.1 142.3	25.0 36.6 75.9
Average Delay (sec)	77.4	37.7	60.1	31.6	113.4	54.1
Number of Runs	12	12	16	18	15	15
Length (feet)	7,887	7,854	7,892	7,846	7,890	7,846

[1]Bolded direction indicates the direction of traffic which is favored by signal timings.
[2]Neither direction is significantly favored by existing signal timings.
[3]Limits of the range of average speed calculated based on the 95% confidence interval.

Note: Posted Speed Limit: 33rd Street – 56th Street = 35 mph
Ideal Travel Time = 153.3 seconds (2 minutes 33.3 seconds)

Table 11b: "After Travel Time Studies-Pioneers Boulevard (56th Street-33rd Street)

"AFTER"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM	
Date of Study Day 1: Day 2:	Thur., 10/12/00 Fri., 10/13/00		Thur., 10/12/00 Fri., 10/13/00		Thur., 10/12/00 Fri., 10/13/00	
Travel Time Statistic	EB	**WB**[1]	EB[2]	WB[2]	EB	**WB**[1]
Average Travel Time (sec)	233.1	200.6	229.0	183.7	260.2	213.4
Standard Deviation (sec)	32.1	26.9	35.0	27.0	39.0	20.4
Average Number of Stops	2.2	1.4	1.8	1.0	2.7	1.7
Average Speed (mph)	23.1	26.7	23.5	29.1	20.6	25.1
Standard Deviation (mph)	3.6	3.4	4.3	4.3	3.7	2.4
95% Confidence Interval (mph)	2.2	2.0	2.5	2.6	1.9	1.3
Average Speeds Within This Range (mph)[3] Lower Limit: Upper Limit:	20.9 25.3	24.7 28.7	21.0 26.0	26.5 31.7	18.7 22.5	23.8 26.4
Time Duration Below: 0 mph 7 mph 28 mph	45.0 58.2 101.4	15.6 22.8 71.6	54.9 61.6 95.1	15.5 19.8 48.4	67.5 80.1 135.0	25.6 33.6 89.6
Average Delay (sec)	79.4	47.8	75.4	31.0	106.8	60.6
Number of Runs	13	14	14	13	17	16
Length (feet)	7,890	7,842	7,886	7,837	7,876	7,843

From the results of the "after" studies, average speeds along Pioneers Boulevard are greater than 20 mph. From a general standpoint, decreases in average speeds were observed between the "before" and "after" travel time studies. Since the north/south arterials that intersect Pioneers Boulevard (i.e., 33rd Street, 40th Street, 48th Street, 56th Street) carry greater traffic volumes than does Pioneers Boulevard, greater emphasis, or priority, was given to the coordination of signals along these north/south roadways. Therefore, decreases in average speed along this corridor were not unexpected. Although deviations in the average speeds do exist, as represented by the upper and lower limits of the confidence interval, decreases in average speed were as great as 1.7 mph. Individual links that experienced average speeds less than 18 mph during the "after" studies are summarized in Table 12.

Table 12

Time Period	Direction	Link	Average Speed (mph)
AM Peak	Eastbound	None	
	Westbound	Allendale Ped Signal – 33rd Street	17.4
Midday	Eastbound	46th/47th Ped Signal – 48th Street	12.7
	Westbound	None	
PM Peak	Eastbound	46th/47th Ped Signal – 48th Street	12.3
		48th Street – 56th Street	16.4
	Westbound	None	

Note: Posted Speed Limit: 33rd Street – 56th Street = 35 mph

From the detailed link statistics, as provided in Appendix A, additional conclusions can be drawn for operations along the Pioneers Boulevard corridor. In the eastbound direction during the PM Peak time period, the link between 48th Street and 56th Street experienced an average of 1.1 stops. This indicates that on at least one occasion, the study vehicle waited through two signal cycles at the intersection of 56th Street/Pioneers Boulevard before continuing eastbound. Operations similar to this occur during the PM Peak in the westbound direction at the intersection of 40th Street/Pioneers Boulevard, where on average, 1.1 stops were experienced on this link.

2.1.7 Vine Street (70th Street to 14th Street; 4.0 miles)

Tables 13a and 13b summarize the results of the travel time studies conducted along Vine Street. The limits of this corridor were defined by the intersection at 70th Street on the east and 14th Street on the west. This corridor is characterized by educational institutions (UNL) on the far west, to commercial uses at the intersections of 27th Street, 45th Street, 48th Street and 70th Street, and residential uses in between. Vine Street has a posted speed limit of 25 mph between 14th and 17th Streets and 35 mph between 17th and 70th Streets.

Table 13a: "Before" Travel Time Studies-Vine Street (70th Street-14th Street)

"BEFORE"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM	
Date of Study Day 1: Day 2:	Fri., 2/11/00 Tue., 2/22/00		Fri., 2/11/00 Mon., 2/14/00		Wed., 2/2/00 Thur., 2/3/00	
Travel Time Statistic	EB	**WB**[1]	EB[2]	WB[2]	**EB**[1]	WB
Average Travel Time (sec)	614.4	582.2	579.2	626.2	635.6	588.6
Standard Deviation (sec)	27.8	65.8	36.1	48.6	79.8	47.7
Average Number of Stops	5.9	3.8	5.0	5.1	5.3	5.0
Average Speed (mph)	23.2	24.6	24.7	22.8	22.5	24.2
Standard Deviation (mph)	1.1	2.6	1.6	1.6	2.8	1.9
95% Confidence Interval (mph)	0.9	2.2	1.2	1.2	2.3	1.6
Average Speeds Within This Range (mph)[3] Lower Limit: Upper Limit:	22.3 24.1	22.4 26.8	23.5 25.9	21.6 24.0	20.2 24.8	22.6 25.8
Time Duration Below: 0 mph 7 mph 28 mph	117.8 143.3 274.0	109.4 126.8 234.0	92.9 126.8 244.6	136.0 172.9 294.5	112.0 148.6 319.9	73.0 111.9 262.9
Average Delay (sec)	196.6	165.1	163.5	211.1	217.2	171.1
Number of Runs	8	8	9	9	8	8
Length (feet)	20,941	20,967	20,963	20,967	20,957	20,924

[1]Bolded direction indicates the direction of traffic which is favored by signal timings.
[2]Neither direction is significantly favored by existing signal timings.
[3]Limits of the range of average speed calculated based on the 95% confidence interval.

Note: Posted Speed Limit: 14th Street – 17th Street = 25 mph
17th Street – 70th Street = 35 mph
Ideal Travel Time = 416.9 seconds (6 minutes 56.9 seconds)

Table 13b: "After" Travel Time Studies-Vine Street (70th Street-14th Street)

"AFTER"	AM Peak 7:00 AM – 8:30 AM		Midday 11:00 AM – 1:00 PM		PM Peak 4:00 PM – 6:00 PM	
Date of Study Day 1: Day 2: Day 3:	Tue., 10/3/00 Wed., 10/4/00 Wed., 11/15/00		Tue., 10/3/00 - Wed., 10/4/00		Tue., 10/3/00 - Wed., 10/4/00	
Travel Time Statistic	EB	**WB**[1]	EB[2]	WB[2]	**EB**[1]	WB
Average Travel Time (sec)	556.0	608.4	592.9	540.8	663.7	665.1
Standard Deviation (sec)	30.5	80.5	24.5	36.8	68.8	40.5
Average Number of Stops	4.5	4.9	6.0	3.2	5.9	7.2
Average Speed (mph)	25.7	23.5	24.1	26.4	21.5	21.5
Standard Deviation (mph)	1.5	2.8	1.0	1.9	2.3	1.3
95% Confidence Interval (mph)	1.1	2.2	0.8	1.5	1.8	1.0
Average Speeds Within This Range (mph)[3] Lower Limit: Upper Limit:	24.6 26.8	21.3 25.7	23.3 24.9	24.9 27.9	19.7 23.3	20.5 22.5
Time Duration Below: 0 mph 7 mph 28 mph	72.2 95.6 219.0	126.7 154.0 275.0	100.0 132.5 254.9	61.2 78.4 199.6	135.4 172.4 346.6	138.8 183.0 345.6
Average Delay (sec)	139.1	192.9	176.2	122.7	245.2	246.6
Number of Runs	10	9	9	9	9	9
Length (feet)	20,951	20,934	20,963	20,947	20,964	20,960

From the results of the "after" studies, average speeds along Vine Street exceed 20 mph. From a general standpoint, both increases and decreases between the "before" and "after" average speeds were observed. Increases in average speed of 2.5 mph and 3.6 mph were observed in the AM Peak, eastbound direction and Midday time period, westbound direction, respectively. Decreases in average speed up to 2.7 mph were experienced. Individual links that experienced average speeds less than 18 mph during the "after" studies are summarized in Table 14.

Table 14

Time Period	Direction	Link	Average Speed (mph)
AM Peak	Eastbound	14th Street – 16th Street	15.2
		45th Street – 48th Street	11.3
	Westbound	66th Street – Cotner Boulevard	16.8
		El Avado Ave. Ped Signal – 48th Street	13.1
		17th Street – 16th Street	12.2
		16th Street – 14th Street	16.3
Midday	Eastbound	14th Street – 16th Street	10.3
		16th Street – 17th Street	9.4
	Westbound	El Avado Ave. Ped Signal – 48th Street	17.2
		16th Street – 14th Street	13.8
PM Peak	Eastbound	14th Street – 16th Street	13.9
		16th Street – 17th Street	10.5
		El Avado Ave. Ped Signal – 56th Street	15.0
		Cotner Boulevard – 66th Street	17.8
		66th Street – 70th Street	16.3
	Westbound	66th Street – Cotner Boulevard	13.1
		El Avado Ave. Ped Signal – 48th Street	10.8
		17th Street – 16th Street	10.7
		16th Street – 14th Street	13.6

Note: Posted Speed Limit: 14th Street – 17th Street = 25 mph
17th Street – 70th Street = 35 mph

As summarized in Table 14, Vine Street experiences low average speeds within the boundaries of the University of Nebraska City campus (14th – 17th Streets). Two probable reasons for these low average speeds are the posted speed limit of 25 mph and very high pedestrian volumes.

Low average speeds were also observed between 66th Street and Cotner Boulevard during the AM and PM Peak time periods. One probable reason for low speeds along this segment results from the mode the traffic signal controller at the intersection of Cotner Boulevard/Vine Street is programmed to operate. Due to high volumes of both pedestrian and vehicular traffic at this intersection, unique signal phasing was implemented at the completion of construction to accommodate this mix of traffic volumes. This unique signal phasing resulted in the traffic signal controller being set to operate in "free" operation. "Free" operation refers to an intersection that is uncoordinated, or is not intended to provide vehicular progression between signalized intersections along a given roadway.

Most other links that were found to have low average speeds are those defined by major signalized intersections at their downstream ends.

From the detailed link statistics, as provided in Appendix A, additional conclusions can be drawn for operations along the Vine Street corridor. In the westbound direction during the AM Peak time period, the link between 27th Street and 17th Street experienced an average of 1.2 stops. This indicates that on at least one occasion, the study vehicle waited through two signal cycles at the intersection of 17th Street/Vine Street before continuing westbound. Operations similar to this occur during the Midday time period in the eastbound direction between the intersections of 14th Street and 16th Street, where an average of 1.1 stops was experienced. These multiple stops are caused by pedestrians, either at the intersection of 16th/Vine Streets or at the mid-block crossing between 14th and 16th Streets. During the PM Peak, an average of 1.2 stops in the westbound direction were experienced at the intersection of 17th/Vine Streets.

2.2 Intersection Delay Studies

In addition to conducting travel time studies, intersection delay studies were conducted to evaluate the changes in operational performance due to signal timing modifications. While travel time studies are beneficial in assessing how well signal timings are coordinated between intersections and whether or not vehicles can progress through a series of intersections without being stopped, delay studies measure the average amount of time vehicles are stopped, or delayed, at signalized intersections. Furthermore, where travel time studies evaluate the performance of operations along the specific corridor, delay studies also measure vehicle delays on the cross-street approaches.

Stopped-vehicle delay was measured at 34 signalized intersections, as shown in Figure 4, by conducting stopped delay studies during the AM Peak, Midday and PM Peak time periods, both "before" and "after" new signal timings were implemented. At four of these locations, including the intersections of 27th/Holdrege Streets, 33rd/Vine Streets, 48th/Vine Streets and 48th/Holdrege Streets, delay studies were conducted two times, on separate days, to test the variability in vehicle delay resulting from collecting data on different days. These "dual studies" were performed for both the "before" and "after" conditions.

"Before" intersection delay studies were also conducted as part of Phase I of this project at 23 signalized intersections along the 27th Street and Highway 2 corridors during a low-volume, off-peak time period, which was identified from 10:30 p.m. to 12:00 midnight. Results of the "before" studies for the three peak time periods and the low-volume, off-peak time period have already been submitted as part of Phase I of this contract. "After" intersection delay studies were not conducted for the off-peak time period since no signal timing adjustments were made.

FIGURE 4: INTERSECTION DELAY STUDY LOCATIONS

Delay studies were conducted on days experiencing "average" traffic conditions within the peak one-hour of each study time period. At each of these intersections, the average amount of stopped time each vehicle/driver experienced was estimated by counting the number of vehicles observed as "stopped" at 13-second intervals, for each approach of the intersection. By making the assumption that each observed vehicle was stopped for the entire 13-second interval, the number of observed vehicles is multiplied by 13 seconds to obtain the total amount of intersection delay. This number is then divided by the total traffic volume to determine the average delay per vehicle for the entire intersection.

Delay is a complex measure and is dependent on a number of variables, including quality of progression, traffic volumes, signal timing parameters and intersection capacity. Another way of expressing delay is in the form of level-of-service (LOS). Specifically, LOS criteria are stated in terms of the average delay per vehicle.

It should be noted that the vehicle delay measured in the field is termed stopped vehicle delay, and represents the amount of time a vehicle is stopped at a red light. This is the type of delay utilized by the 1994 *Highway Capacity Manual*. Recent revisions to this document, beginning with the 1997 version and most recently, the 2000 version, have used control delay to identify the LOS intersections are operating under. Control delay is the portion of the total delay attributed to traffic signal operation for signalized intersections. The LOS criteria for stopped delay and control delay are summarized in Table 15.

Table 15: Level-of-Service Criteria (Signalized Intersections)

Level-of-Service[1]	1994 Highway Capacity Manual Stopped Delay/Vehicle (sec)	2000 Highway Capacity Manual Control Delay/Vehicle (sec)
A	≤ 5	≤ 10
B	> 5 and ≤ 15	> 10 and ≤ 20
C	> 15 and ≤ 25	> 20 and ≤ 35
D	> 25 and ≤ 40	> 35 and ≤ 55
E	> 40 and ≤ 60	> 55 and ≤ 80
F	> 60	> 80

[1] LOS A – occurs when progression is extremely favorable and most vehicles arrive during the green phase.
LOS B – generally occurs with good progression, short cycle lengths or both.
LOS C – exhibits higher delays resulting from fair progression and/or longer cycle lengths, with a significant number of vehicles stopping.
LOS D – longer delays resulting from unfavorable progression, and high volume-to-capacity (V/C) ratios, with many vehicles stopping.
LOS E – exhibits higher delay due to poor progression, long cycle lengths and high V/C ratios.
LOS F – considered unacceptable to most drivers and often occurs when arrival flow rates exceed the capacity of the intersection.

Control delay includes initial deceleration delay, queue move-up time, stopped delay and final acceleration delay. According to the 2000 *Highway Capacity Manual* (HCM), control delay is approximately 30% greater than stopped delay. Since it is difficult to measure control delay in the field for every vehicle approaching an intersection, stopped delay was measured, as outlined in ITE's *Manual of Transportation Engineering Studies*, multiplied by 1.3, and cross-referenced to Table 15 to identify what LOS the intersection is operating under per the 2000 HCM criteria. Throughout the remainder of this chapter, references to intersection LOS pertain to the 2000 HCM criteria.

Reasons for different improvements in intersection delay versus average travel-speed on study corridors are twofold. One, when performing the traffic signal optimization analysis, attention was given to the intersection approaches on the study corridors as well as the approaches of the cross-streets. Therefore, many of the reductions in intersection delay are a result of decreases in delay on all four approaches to the intersection and not just the two approaches pertaining to the study corridors. These improvements for cross-street traffic are not represented in the analysis of the travel-time corridors. The second reason for the greater improvements in intersection delay relates to the sub-system analysis. Sub-system analysis was performed as part of the signal timing analysis and will be discussed in Section 4.0. Many of the decreases in average travel-speed are a result of increased delays at the intersections where sub-systems are broken. The remaining intersections are experiencing efficient operation in terms of both signal timings and progression, which result in lower delays.

The following six sections summarize the results of the "before" and "after" intersection delay studies conducted at locations along each of the six corridors. Detailed "after" intersection delay summaries for each intersection are provided in Appendix B. Summaries of the "before" intersection delay studies were previously submitted as part of Phase I of this project. Dates when intersection delay studies were conducted are also provided in Appendix B.

2.2.1 North 27th Street

Intersection delay studies were conducted at five (5) signalized intersections along this corridor. Table 16 summarizes the results of both the "before" and "after" intersection delay studies. Delay and LOS are reported for the overall intersection as well as for each individual approach for each of the three peak time periods. Delay study computations for each intersection are provided in Appendix B.

In general, most of the intersections along the corridor showed an increase in overall intersection delay from the "before" study to the "after" study during the AM Peak. During the Midday, both decreases and increases in average delay were observed. Overall intersection delay decreased at most intersections during the PM Peak time period.

Of the five (5) intersections studied, the intersection of 27th Street/Vine Street experienced a decrease in overall intersection delay during all three time periods between the "before" and "after" delay studies, with a corresponding increase in LOS during the Midday and PM Peak time periods, according to the 2000 HCM criteria. Both the intersection at Holdrege Street and the intersection at Cornhusker Highway decrease from LOS 'C' to LOS 'D' during the AM Peak. The decrease in LOS was partly due to an increase in traffic volume being serviced by the intersection during the "after" studies, resulting in a higher number of stopped vehicles recorded during the study time period.

The intersection of 27th Street/Superior Street experienced a significant increase in average stopped delay during both the AM Peak and Midday time periods, resulting in a decrease in LOS from 'C' to 'D'. Again, the decrease in LOS was, in part, due to an increase in traffic volume being serviced by the intersection during the "after" studies, especially for both the northbound and southbound approaches, resulting in a higher number of stopped vehicles recorded during the study time period.

Dual intersection delay studies were conducted at the intersection of 27th Street/Holdrege Street for both the "before" and "after" scenarios to determine the variability in delay resulting from collecting data on different days. Comparison of the dual delay studies conducted showed very little variability in average stopped delay between the two days on which the studies were conducted. The greatest variability of 4.6 sec/veh was observed for the "after" study during the PM Peak time period. Otherwise, variability remained less than 2.0 sec/veh for all other time periods for both the "before" and "after" studies.

Table 16: Intersection Delay Studies - North 27th Street

Intersection	Approach	AM Peak								Midday								PM Peak							
		"Before"				"After"				"Before"				"After"				"Before"				"After"			
		Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS
Vine Street	**Overall**	**26.5**	**34.5**	**D**	**C**	**17.1**	**22.2**	**C**	**C**	**27.5**	**35.8**	**D**	**D**	**18.5**	**24.1**	**C**	**C**	**46.3**	**60.2**	**E**	**E**	**29.0**	**37.7**	**D**	**D**
	NB	5.6	7.3	B	A	12.8	16.6	B	B	21.6	28.1	C	C	21.2	27.6	C	C	33.5	43.6	D	D	39.5	51.4	D	D
	SB	27.7	36.0	D	D	12.5	16.3	B	B	16.6	21.6	C	C	11.5	15.0	B	B	101.7	132.2	F	F	22.5	29.3	C	C
	EB	36.7	47.7	D	D	24.8	32.2	C	C	38.7	50.3	D	D	26.4	34.3	D	C	25.0	32.5	C	C	29.9	38.9	D	D
	WB	38.9	50.6	D	D	27.2	35.4	D	D	41.5	54.0	E	D	21.1	27.4	C	C	20.4	26.5	C	C	20.2	26.3	C	C
Holdrege Street #1	**Overall**	**17.7**	**23.0**	**C**	**C**	**29.9**	**38.9**	**D**	**D**	**16.3**	**21.2**	**C**	**C**	**17.6**	**22.9**	**C**	**C**	**31.3**	**40.7**	**D**	**D**	**28.5**	**37.1**	**D**	**D**
	NB	12.5	16.3	B	B	31.1	40.4	D	D	12.2	15.9	B	B	11.3	14.7	B	B	25.2	32.8	D	C	16.5	21.5	C	C
	SB	16.6	21.6	C	C	27.0	35.1	D	D	4.4	5.7	A	A	10.3	13.4	B	B	42.7	55.5	E	E	24.1	31.3	C	C
	EB	28.7	37.3	D	D	32.9	42.8	D	D	28.9	37.6	D	D	27.9	36.3	D	D	39.5	51.4	D	D	35.6	46.3	D	D
	WB	17.8	23.1	C	C	30.9	40.2	D	D	31.2	40.6	D	D	28.4	36.9	D	D	18.0	23.4	C	C	45.2	58.8	E	E
Holdrege Street #2	**Overall**	**18.3**	**23.8**	**C**	**C**	**28.5**	**37.1**	**D**	**D**	**16.3**	**21.2**	**C**	**C**	**18.0**	**23.4**	**C**	**C**	**31.0**	**40.3**	**D**	**D**	**23.9**	**31.1**	**C**	**C**
	NB	9.7	12.6	B	B	28.6	37.2	D	D	12.8	16.6	B	B	15.7	20.4	C	C	25.9	33.7	D	C	23.2	30.2	C	C
	SB	16.8	21.8	C	C	24.6	32.0	C	C	6.7	8.7	B	A	9.6	12.5	B	B	39.5	51.4	D	D	20.2	26.3	C	C
	EB	29.5	38.4	D	D	41.9	54.5	E	D	20.1	26.1	C	C	26.2	34.1	D	C	28.3	36.8	D	D	29.2	38.0	D	D
	WB	22.6	29.4	C	C	24.6	32.0	C	C	28.2	36.7	D	D	27.3	35.5	D	D	31.2	40.6	D	D	25.9	33.7	D	C
Cornhusker Highway	**Overall**	**24.4**	**31.7**	**C**	**C**	**36.7**	**47.7**	**D**	**D**	**22.2**	**28.9**	**C**	**C**	**19.4**	**25.2**	**C**	**C**	**31.9**	**41.5**	**D**	**D**	**29.3**	**38.1**	**D**	**D**
	NB	22.4	29.1	C	C	39.5	51.4	D	D	26.4	34.3	D	C	18.7	24.3	C	C	53.7	69.8	E	E	24.8	32.2	C	C
	SB	24.8	32.2	C	C	36.3	47.2	D	D	27.4	35.6	D	D	29.1	37.8	D	D	35.2	45.8	D	D	47.0	61.1	E	E
	EB	25.0	32.5	C	C	44.8	58.2	E	E	16.5	21.5	C	C	14.7	19.1	B	B	23.7	30.8	C	C	25.8	33.5	D	C
	WB	24.7	32.1	C	C	28.3	36.8	D	D	17.8	23.1	C	C	14.7	19.1	B	B	17.1	22.2	C	C	21.9	28.5	C	C
Kmart Drive	**Overall**	**1.5**	**2.0**	**A**	**A**	**2.2**	**2.9**	**A**	**A**	**11.4**	**14.8**	**B**	**B**	**8.4**	**10.9**	**B**	**B**	**8.4**	**10.9**	**B**	**B**	**13.8**	**17.9**	**B**	**B**
	NB	0.5	0.7	A	A	1.2	1.6	A	A	3.8	4.9	A	A	2.7	3.5	A	A	4.3	5.6	A	A	8.3	10.8	B	B
	SB	0.4	0.5	A	A	0.9	1.2	A	A	12.8	16.6	B	B	7.7	10.0	B	B	8.4	10.9	B	B	9.0	11.7	B	B
	EB	0.0	0.0	-	-	34.7	45.1	D	D	25.7	33.4	D	C	34.2	44.5	D	D	22.6	29.4	C	C	45.5	59.2	E	E
	WB	35.5	46.2	D	D	50.7	65.9	E	E	23.2	30.2	C	C	22.0	28.6	C	C	20.7	26.9	C	C	43.4	56.4	E	E
Superior Street	**Overall**	**18.1**	**23.5**	**C**	**C**	**29.4**	**38.2**	**D**	**D**	**23.1**	**30.0**	**C**	**C**	**33.7**	**43.8**	**D**	**D**	**35.5**	**46.2**	**D**	**D**	**33.6**	**43.7**	**D**	**D**
	NB	32.8	42.6	D	D	54.6	71.0	E	E	24.5	31.9	C	C	43.3	56.3	E	E	37.0	48.1	D	D	39.2	51.0	D	D
	SB	19.9	25.9	C	C	28.7	37.3	D	D	24.8	32.2	C	C	28.4	36.9	D	D	35.2	45.8	D	D	44.6	58.0	E	E
	EB	12.6	16.4	B	B	31.9	41.5	D	D	17.3	22.5	C	C	28.3	36.8	D	D	25.0	32.5	C	C	28.1	36.5	D	D
	WB	18.7	24.3	C	C	14.1	18.3	B	B	25.9	33.7	D	C	34.4	44.7	D	D	44.4	57.7	E	E	26.2	34.1	D	C

2.2.2 North 48th Street

Intersection delay studies were conducted at seven (7) signalized intersections along this corridor. Table 17 summarizes the results of both the "before" and "after" intersection delay studies. Delay and LOS are reported for the overall intersection as well as for each individual approach for each of the three peak time periods. Delay study computations for each intersection are provided in Appendix B.

From a general perspective, most intersections were observed to increase in overall average intersection delay between "before" and "after" studies. However, during the AM Peak and Midday time periods, all intersections maintained LOS 'C' or better with the exception of 48th Street/Cornhusker Hwy, which decreased from LOS 'C' to LOS 'D' during the AM Peak. "After" studies for the PM Peak showed the intersections at Vine Street, Holdrege Street and Cornhusker Highway to be operating at LOS 'D', with the remaining intersections operating at LOS 'C', or better.

Dual intersection delay studies were conducted at the intersections of 48th Street/Vine Street and 48th Street/Holdrege Street for both the "before" and "after" scenarios to determine the variability in delay resulting from collecting data on different days. Variability between stopped delay measured on different days for both the "before" and "after" studies at the intersection of 48th Street/Vine Street was no greater than 7.1 sec/veh. At the intersection of 48th Street/Holdrege Street, variability ranged from 1.1 sec/veh to 9.5 sec/veh. However, with the exception of the "after" study for the PM Peak time period, variability was less than or equal to 4.2 sec/veh for all other time periods for both the "before" and "after" studies at the Holdrege Street intersection.

Table 17: Intersection Delay Studies - North 48th Street

Intersection	Approach	AM Peak								Midday								PM Peak							
		"Before"				"After"				"Before"				"After"				"Before"				"After"			
		Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS
"R" Street	**Overall**	**10.6**	**13.8**	**B**	**B**	**13.9**	**18.1**	**B**	**B**	**19.9**	**25.9**	**C**	**C**	**17.9**	**23.3**	**C**	**C**	**21.3**	**27.7**	**C**	**C**	**20.1**	**26.1**	**C**	**C**
	NB	1.7	2.2	A	A	5.2	6.8	B	A	10.3	13.4	B	B	15.8	20.5	C	C	20.4	26.5	C	C	8.1	10.5	B	B
	SB	5.6	7.3	B	A	7.5	9.8	B	A	18.1	23.5	C	C	13.9	18.1	B	B	6.0	7.8	B	A	13.0	16.9	B	B
	EB	37.1	48.2	D	D	42.6	55.4	E	E	28.3	36.8	D	D	28.3	36.8	D	D	41.5	54.0	E	D	44.3	57.6	E	E
	WB	35.8	46.5	D	D	33.6	43.7	D	D	35.5	46.2	D	D	23.1	30.0	C	C	42.4	55.1	E	E	38.2	49.7	D	D
Vine Street #1	**Overall**	**16.1**	**20.9**	**C**	**C**	**24.1**	**31.3**	**C**	**C**	**17.1**	**22.2**	**C**	**C**	**18.5**	**24.1**	**C**	**C**	**26.0**	**33.8**	**D**	**C**	**30.5**	**39.7**	**D**	**D**
	NB	16.1	20.9	C	C	11.5	15.0	B	B	14.4	18.7	B	B	19.3	25.1	C	C	29.7	38.6	D	D	25.8	33.5	D	C
	SB	14.5	18.9	B	B	26.8	34.8	D	C	8.3	10.8	B	B	15.4	20.0	C	C	18.8	24.4	C	C	17.6	22.9	C	C
	EB	26.7	34.7	D	C	26.7	34.7	D	C	25.7	33.4	D	C	15.1	19.6	C	B	31.4	40.8	D	D	38.6	50.2	D	D
	WB	19.1	24.8	C	C	31.6	41.1	D	D	28.8	37.4	D	D	40.4	52.5	E	D	21.9	28.5	C	C	54.3	70.6	E	E
Vine Street #2	**Overall**	**18.1**	**23.5**	**C**	**C**	**19.5**	**25.4**	**C**	**C**	**10.0**	**13.0**	**B**	**B**	**18.5**	**24.1**	**C**	**C**	**30.9**	**40.2**	**D**	**D**	**30.3**	**39.4**	**D**	**D**
	NB	9.4	12.2	B	B	10.4	13.5	B	B	11.7	15.2	B	B	14.7	19.1	B	B	30.4	39.5	D	D	22.0	28.6	C	C
	SB	14.8	19.2	B	B	18.3	23.8	C	C	12.3	16.0	B	B	18.3	23.8	C	C	36.4	47.3	D	D	21.5	28.0	C	C
	EB	17.9	23.3	C	C	21.7	28.2	C	C	7.8	10.1	B	B	16.5	21.5	C	C	29.9	38.9	D	D	35.8	46.5	D	D
	WB	31.5	41.0	D	D	27.5	35.8	D	D	5.4	7.0	B	A	24.7	32.1	C	C	20.8	27.0	C	C	61.6	80.1	F	F
Holdrege Street #1	**Overall**	**20.7**	**26.9**	**C**	**C**	**22.5**	**29.3**	**C**	**C**	**17.2**	**22.4**	**C**	**C**	**11.6**	**15.1**	**B**	**B**	**20.9**	**27.2**	**C**	**C**	**28.1**	**36.5**	**D**	**D**
	NB	8.8	11.4	B	B	10.8	14.0	B	B	17.5	22.8	C	C	13.5	17.6	B	B	23.2	30.2	C	C	38.1	49.5	D	D
	SB	25.9	33.7	D	C	22.4	29.1	C	C	14.5	18.9	B	B	9.9	12.9	B	B	27.7	36.0	D	D	33.4	43.4	D	D
	EB	24.5	31.9	C	C	28.5	37.1	D	D	18.4	23.9	C	C	20.6	26.8	C	C	14.1	18.3	B	B	15.2	19.8	C	B
	WB	26.9	35.0	D	C	31.6	41.1	D	D	20.1	26.1	C	C	5.8	7.5	B	A	10.8	14.0	B	B	16.8	21.8	C	C
Holdrege Street #2	**Overall**	**19.3**	**25.1**	**C**	**C**	**21.4**	**27.8**	**C**	**C**	**15.4**	**20.0**	**C**	**C**	**15.8**	**20.5**	**C**	**C**	**26.6**	**34.6**	**D**	**C**	**37.6**	**48.9**	**D**	**D**
	NB	11.3	14.7	B	B	12.7	16.5	B	B	19.6	25.5	C	C	16.5	21.5	C	C	23.6	30.7	C	C	47.0	61.1	E	E
	SB	18.7	24.3	C	C	21.3	27.7	C	C	13.6	17.7	B	B	14.5	18.9	B	B	42.7	55.5	E	E	48.9	63.6	E	E
	EB	26.7	34.7	D	C	28.5	37.1	D	D	15.1	19.6	C	B	18.5	24.1	C	C	15.9	20.7	C	C	19.8	25.7	C	C
	WB	25.2	32.8	D	C	28.6	37.2	D	D	10.0	13.0	B	B	12.2	15.9	B	B	14.2	18.5	B	B	17.5	22.8	C	C
Leighton Avenue	**Overall**	**7.9**	**10.3**	**B**	**B**	**19.2**	**25.0**	**C**	**C**	**11.1**	**14.4**	**B**	**B**	**10.5**	**13.7**	**B**	**B**	**11.2**	**14.6**	**B**	**B**	**21.3**	**27.7**	**C**	**C**
	NB	6.0	7.8	B	A	19.9	25.9	C	C	6.3	8.2	B	A	8.7	11.3	B	B	9.1	11.8	B	B	19.2	25.0	C	C
	SB	2.3	3.0	A	A	7.7	10.0	B	B	8.6	11.2	B	B	5.7	7.4	B	A	6.4	8.3	B	A	16.9	22.0	C	C
	EB	6.9	9.0	B	A	21.1	27.4	C	C	17.2	22.4	C	C	16.7	21.7	C	C	16.7	21.7	C	C	22.5	29.3	C	C
	WB	26.8	34.8	D	C	44.7	58.1	E	E	31.5	41.0	D	D	26.4	34.3	D	C	39.8	51.7	D	D	45.0	58.5	E	E
Adams Street	**Overall**	**7.2**	**9.4**	**B**	**A**	**13.5**	**17.6**	**B**	**B**	**7.1**	**9.2**	**B**	**A**	**11.8**	**15.3**	**B**	**B**	**9.5**	**12.4**	**B**	**B**	**18.4**	**23.9**	**C**	**C**
	NB	5.9	7.7	B	A	3.9	5.1	A	A	4.0	5.2	A	A	6.5	8.5	B	A	8.1	10.5	B	B	11.1	14.4	B	B
	SB	4.1	5.3	A	A	19.6	25.5	C	C	7.3	9.5	B	A	8.5	11.1	B	B	9.0	11.7	B	B	20.0	26.0	C	C
	EB	10.9	14.2	B	B	16.2	21.1	C	C	9.5	12.4	B	B	15.4	20.0	C	C	12.2	15.9	B	B	23.8	30.9	C	C
	WB	13.0	16.9	B	B	10.3	13.4	B	B	9.9	12.9	B	B	21.8	28.3	C	C	9.8	12.7	B	B	24.2	31.5	C	C
Cornhusker Highway	**Overall**	**22.2**	**28.9**	**C**	**C**	**29.7**	**38.6**	**D**	**D**	**17.6**	**22.9**	**C**	**C**	**20.7**	**26.9**	**C**	**C**	**28.5**	**37.1**	**D**	**D**	**31.4**	**40.8**	**D**	**D**
	NB	12.4	16.1	B	B	27.7	36.0	D	D	10.2	13.3	B	B	22.3	29.0	C	C	20.0	26.0	C	C	16.0	20.8	C	C
	SB	18.5	24.1	C	C	56.6	73.6	E	E	24.0	31.2	C	C	26.0	33.8	D	C	31.1	40.4	D	D	53.5	69.6	E	E
	EB	34.9	45.4	D	D	31.4	40.8	D	D	16.1	20.9	C	C	16.6	21.6	C	C	38.1	49.5	D	D	43.3	56.3	E	E
	WB	30.8	40.0	D	D	14.6	19.0	B	B	21.7	28.2	C	C	18.5	24.1	C	C	26.1	33.9	D	C	25.4	33.0	D	C
Superior Street	**Overall**	**4.4**	**5.7**	**A**	**A**	**3.1**	**4.0**	**A**	**A**	**6.5**	**8.5**	**B**	**A**	**4.6**	**6.0**	**A**	**A**	**6.7**	**8.7**	**B**	**A**	**7.2**	**9.4**	**B**	**A**
	NB	11.0	14.3	B	B	8.5	11.1	B	B	14.6	19.0	B	B	6.2	8.1	B	A	14.4	18.7	B	B	12.3	16.0	B	B
	SB	11.0	14.3	B	B	19.5	25.4	C	C	8.9	11.6	B	B	7.1	9.2	B	A	5.3	6.9	B	A	9.8	12.7	B	B
	EB	2.6	3.4	A	A	1.9	2.5	A	A	4.5	5.9	A	A	4.2	5.5	A	A	4.4	5.7	A	A	5.3	6.9	B	A
	WB	2.8	3.6	A	A	1.6	2.1	A	A	3.6	4.7	A	A	3.4	4.4	A	A	6.3	8.2	B	A	5.9	7.7	B	A

2.2.3 North 70th Street

Intersection delay studies were conducted at four (4) signalized intersections along this corridor. Table 18 summarizes the results of both the "before" and "after" intersection delay studies. Delay and LOS are reported for the overall intersection as well as for each individual approach for each of the three peak time periods. Delay study computations for each intersection are provided in Appendix B.

Results of the "after" intersection delay studies show all the intersections observed along this corridor to be operating at LOS 'C', or better, during each of the three time periods. Overall intersection delay decreased between "before" and "after" studies during at least two of the three time periods for each intersection. Intersection delay decreased during all three time periods for the intersection of 70th Street/Holdrege Street. In general, each intersection is operating at LOS 'C' or better during each of the three time periods. The only decrease in LOS between the "before" and "after" studies was at the intersection of 70th Street/Adams Street, with the LOS decreasing from 'B' to 'C'.

Table 18: Intersection Delay Studies - North 70th Street

Intersection	Approach	AM Peak								Midday								PM Peak							
		"Before"				"After"				"Before"				"After"				"Before"				"After"			
		Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS
Vine Street	**Overall**	**12.8**	**16.6**	**B**	**B**	**13.1**	**17.0**	**B**	**B**	**12.7**	**16.5**	**B**	**B**	**8.4**	**10.9**	**B**	**B**	**18.6**	**24.2**	**C**	**C**	**16.1**	**20.9**	**C**	**C**
	NB	12.3	16.0	B	B	10.3	13.4	B	B	14.8	19.2	B	B	6.6	8.6	B	A	21.5	28.0	C	C	18.6	24.2	C	C
	SB	16.1	20.9	C	C	15.8	20.5	C	C	17.0	22.1	C	C	5.6	7.3	B	A	9.1	11.8	B	B	7.2	9.4	B	A
	EB	6.1	7.9	B	A	15.1	19.6	C	B	5.4	7.0	B	A	9.9	12.9	B	B	24.0	31.2	C	C	23.4	30.4	C	C
	WB	12.0	15.6	B	B	10.7	13.9	B	B	10.9	14.2	B	B	14.8	19.2	B	B	22.6	29.4	C	C	14.6	19.0	B	B
Holdrege Street	**Overall**	**19.5**	**25.4**	**C**	**C**	**13.2**	**17.2**	**B**	**B**	**14.9**	**19.4**	**B**	**B**	**7.0**	**9.1**	**B**	**A**	**25.8**	**33.5**	**D**	**C**	**14.2**	**18.5**	**B**	**B**
	NB	10.6	13.8	B	B	6.6	8.6	B	A	13.9	18.1	B	B	6.5	8.5	B	A	14.5	18.9	B	B	11.4	14.8	B	B
	SB	30.7	39.9	D	D	9.6	12.5	B	B	16.9	22.0	C	C	7.6	9.9	B	A	15.0	19.5	B	B	13.2	17.2	B	B
	EB	13.1	17.0	B	B	26.3	34.2	D	C	13.6	17.7	B	B	4.2	5.5	A	A	62.7	81.5	F	F	15.4	20.0	C	C
	WB	17.7	23.0	C	C	19.4	25.2	C	C	14.2	18.5	B	B	9.0	11.7	B	B	12.3	16.0	B	B	22.9	29.8	C	C
Adams Street	**Overall**	**13.2**	**17.2**	**B**	**B**	**12.7**	**16.5**	**B**	**B**	**6.7**	**8.7**	**B**	**A**	**6.1**	**7.9**	**B**	**A**	**13.8**	**17.9**	**B**	**B**	**16.5**	**21.5**	**C**	**C**
	NB	15.5	20.2	C	C	11.3	14.7	B	B	5.0	6.5	A	A	6.9	9.0	B	A	10.6	13.8	B	B	12.6	16.4	B	B
	SB	12.6	16.4	B	B	20.5	26.7	C	C	4.1	5.3	A	A	6.8	8.8	B	A	13.3	17.3	B	B	11.4	14.8	B	B
	EB	11.4	14.8	B	B	6.7	8.7	B	A	9.8	12.7	B	B	4.3	5.6	A	A	18.5	24.1	C	C	29.8	38.7	D	D
	WB	13.4	17.4	B	B	11.2	14.6	B	B	10.7	13.9	B	B	5.8	7.5	B	A	13.0	16.9	B	B	13.8	17.9	B	B
Havelock Avenue	**Overall**	**6.2**	**8.1**	**B**	**A**	**5.4**	**7.0**	**B**	**A**	**5.6**	**7.3**	**B**	**A**	**3.8**	**4.9**	**A**	**A**	**7.7**	**10.0**	**B**	**B**	**8.1**	**10.5**	**B**	**B**
	NB	6.0	7.8	B	A	5.0	6.5	A	A	2.3	3.0	A	A	3.1	4.0	A	A	7.0	9.1	B	A	9.2	12.0	B	B
	SB	4.5	5.9	A	A	2.2	2.9	A	A	2.5	3.3	A	A	2.1	2.7	A	A	2.8	3.6	A	A	5.0	6.5	A	A
	EB	6.8	8.8	B	A	7.0	9.1	B	A	9.9	12.9	B	B	5.2	6.8	B	A	12.2	15.9	B	B	6.4	8.3	B	A
	WB	8.0	10.4	B	B	8.3	10.8	B	B	9.5	12.4	B	B	4.8	6.2	A	A	12.5	16.3	B	B	18.1	23.5	C	C

2.2.4 Nebraska Highway 2

Intersection delay studies were conducted at nine (9) signalized intersections related to the operation of this corridor. Table 19 summarizes the results of both the "before" and "after" intersection delay studies. Delay and LOS are reported for the overall intersection as well as for each individual approach for each of the three peak time periods. Delay study computations for each intersection are provided in Appendix B.

"After" intersection delay studies were not conducted for the intersections at 14th Street and 27th Street. This was due to changes in traffic patterns as a result of construction on 14th Street south of Old Cheney Road. Vehicles were subsequently detoured around the construction area, thereby, impacting operations at these two intersections. "Before" studies indicated that these two intersections operate at LOS 'C' during the Midday time period. The intersection at 27th Street operates at LOS 'D' and LOS 'E' during the AM Peak and PM Peak time periods, respectively, while the intersection at 14th Street operates at LOS 'C' during the AM Peak and LOS 'D' during the PM Peak.

With the exception of the two previously mentioned intersections, intersections related to the Highway 2 corridor are operating fairly efficiently. During the AM Peak, "after" studies indicate that most of the intersections are operating at LOS 'C' or better with the exception of the intersection at 40th Street, which decreased from LOS 'C' to LOS 'D'. During the Midday and PM Peak time periods, most intersections saw a decrease in overall intersection delay between the "before" and "after" studies. Most intersections also maintained LOS 'C' or better during the Midday and PM Peak time periods, with the exception of the intersection of 56th Street/Old Cheney Road, which operates at LOS 'D'.

Table 19: Intersection Delay Studies - Nebraska Highway 2

Intersection	Approach	AM Peak								Midday								PM Peak							
		"Before"				"After"				"Before"				"After"				"Before"				"After"			
		Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS
Old Cheney	**Overall**	**13.3**	**17.3**	**B**	**B**	**15.4**	**20.0**	**C**	**C**	**8.6**	**11.2**	**B**	**B**	**17.4**	**22.6**	**C**	**C**	**21.4**	**27.8**	**C**	**C**	**15.3**	**19.9**	**C**	**B**
	NB	27.4	35.6	D	D	49.4	64.2	E	E	10.8	14.0	B	B	33.2	43.2	D	D	27.5	35.8	D	D	19.7	25.6	C	C
	SB	15.9	20.7	C	C	23.0	29.9	C	C	12.2	15.9	B	B	19.1	24.8	C	C	24.1	31.3	C	C	19.9	25.9	C	C
	EB	7.7	10.0	B	B	6.8	8.8	B	A	4.6	6.0	A	A	5.8	7.5	B	A	15.0	19.5	B	B	5.4	7.0	B	A
	WB	3.1	4.0	A	A	4.6	6.0	A	A	4.6	6.0	A	A	5.4	7.0	B	A	14.1	18.3	B	B	13.2	17.2	B	B
56th Street	**Overall**	**16.3**	**21.2**	**C**	**C**	**17.2**	**22.4**	**C**	**C**	**15.7**	**20.4**	**C**	**C**	**15.7**	**20.4**	**C**	**C**	**22.9**	**29.8**	**C**	**C**	**24.9**	**32.4**	**C**	**C**
	NB	26.8	34.8	D	C	28.0	36.4	D	D	24.9	32.4	C	C	29.0	37.7	D	D	30.4	39.5	D	D	56.1	72.9	E	E
	SB	24.2	31.5	C	C	24.3	31.6	C	C	18.2	23.7	C	C	15.6	20.3	C	C	36.5	47.5	D	D	25.3	32.9	D	C
	EB	6.9	9.0	B	A	7.8	10.1	B	B	5.3	6.9	B	A	8.5	11.1	B	B	7.6	9.9	B	A	6.9	9.0	B	A
	WB	10.3	13.4	B	B	11.5	15.0	B	B	12.1	15.7	B	B	7.7	10.0	B	B	15.2	19.8	C	B	12.5	16.3	B	B
48th Street	**Overall**	**16.4**	**21.3**	**C**	**C**	**14.4**	**18.7**	**B**	**B**	**11.9**	**15.5**	**B**	**B**	**12.6**	**16.4**	**B**	**B**	**17.4**	**22.6**	**C**	**C**	**15.6**	**20.3**	**C**	**C**
	NB	30.3	39.4	D	D	25.1	32.6	D	C	13.8	17.9	B	B	17.2	22.4	C	C	26.4	34.3	D	C	33.9	44.1	D	D
	SB	22.2	28.9	C	C	25.4	33.0	D	C	17.6	22.9	C	C	19.1	24.8	C	C	27.4	35.6	D	D	24.7	32.1	C	C
	EB	12.2	15.9	B	B	7.5	9.8	B	A	7.1	9.2	B	A	9.9	12.9	B	B	13.2	17.2	B	B	3.4	4.4	A	A
	WB	8.0	10.4	B	B	4.2	5.5	A	A	11.3	14.7	B	B	7.3	9.5	B	A	8.9	11.6	B	B	9.8	12.7	B	B
40th Street	**Overall**	**19.5**	**25.4**	**C**	**C**	**36.1**	**46.9**	**D**	**D**	**14.6**	**19.0**	**B**	**B**	**13.5**	**17.6**	**B**	**B**	**19.7**	**25.6**	**C**	**C**	**18.5**	**24.1**	**C**	**C**
	NB	31.4	40.8	D	D	72.7	94.5	F	F	23.0	29.9	C	C	22.1	28.7	C	C	32.1	41.7	D	D	28.6	37.2	D	D
	SB	29.4	38.2	D	D	48.6	63.2	E	E	29.9	38.9	D	D	31.8	41.3	D	D	30.8	40.0	D	D	38.9	50.6	D	D
	EB	11.1	14.4	B	B	4.8	6.2	A	A	6.2	8.1	B	A	3.0	3.9	A	A	9.1	11.8	B	B	6.0	7.8	B	A
	WB	5.4	7.0	B	A	4.8	6.2	A	A	7.3	9.5	B	A	6.3	8.2	B	A	15.5	20.2	C	C	8.4	10.9	B	B
27th Street	**Overall**	**40.2**	**52.3**	**E**	**D**	'After' Studies not Conducted				**17.2**	**22.4**	**C**	**C**	'After' Studies not Conducted				**43.2**	**56.2**	**E**	**E**	'After' Studies not Conducted			
	NB	41.5	54.0	E	D					19.2	25.0	C	C					69.1	89.8	F	F				
	SB	24.5	31.9	C	C					19.4	25.2	C	C					74.9	97.4	F	F				
	EB	31.1	40.4	D	D					13.5	17.6	B	B					22.1	28.7	C	C				
	WB	50.6	65.8	E	E					16.8	21.8	C	C					29.5	38.4	D	D				
14th Street	**Overall**	**26.5**	**34.5**	**D**	**C**	'After' Studies not Conducted				**26.9**	**35.0**	**D**	**C**	'After' Studies not Conducted				**40.9**	**53.2**	**E**	**D**	'After' Studies not Conducted			
	NB	25.2	32.8	D	C					33.1	43.0	D	D					52.5	68.3	E	E				
	SB	45.0	58.5	E	E					33.2	43.2	D	D					36.2	47.1	D	D				
	EB	38.4	49.9	D	D					24.3	31.6	C	C					53.8	69.9	E	E				
	WB	17.1	22.2	C	C					17.5	22.8	C	C					21.2	27.6	C	C				
56th St./ Old Cheney Rd.	**Overall**	**23.1**	**30.0**	**C**	**C**	**23.1**	**30.0**	**C**	**C**	**20.2**	**26.3**	**C**	**C**	**23.9**	**31.1**	**C**	**C**	**30.4**	**39.5**	**D**	**D**	**28.8**	**37.4**	**D**	**D**
	NB	21.3	27.7	C	C	31.3	40.7	D	D	13.9	18.1	B	B	9.2	12.0	B	B	17.6	22.9	C	C	31.9	41.5	D	D
	SB	4.6	6.0	A	A	7.7	10.0	B	B	10.8	14.0	B	B	26.6	34.6	D	C	7.8	10.1	B	B	11.2	14.6	B	B
	EB	27.6	35.9	D	D	41.7	54.2	E	D	28.0	36.4	D	D	27.8	36.1	D	D	38.5	50.1	D	D	35.7	46.4	D	D
	WB	33.0	42.9	D	D	14.9	19.4	B	B	25.0	32.5	C	C	31.7	41.2	D	D	53.8	69.9	E	E	36.7	47.7	D	D
48th St./ Old Cheney Rd.	**Overall**	**10.9**	**14.2**	**B**	**B**	**12.0**	**15.6**	**B**	**B**	**8.7**	**11.3**	**B**	**B**	**13.4**	**17.4**	**B**	**B**	**20.7**	**26.9**	**C**	**C**	**13.8**	**17.9**	**B**	**B**
	NB	20.3	26.4	C	C	24.4	31.7	C	C	18.8	24.4	C	C	19.3	25.1	C	C	23.6	30.7	C	C	25.7	33.4	D	C
	SB	16.9	22.0	C	C	15.6	20.3	C	C	11.3	14.7	B	B	15.8	20.5	C	C	22.2	28.9	C	C	14.4	18.7	B	B
	EB	8.4	10.9	B	B	10.2	13.3	B	B	7.8	10.1	B	B	10.2	13.3	B	B	12.4	16.1	B	B	16.0	20.8	C	C
	WB	9.7	12.6	B	B	10.2	13.3	B	B	5.2	6.8	B	A	13.8	17.9	B	B	26.5	34.5	D	C	8.3	10.8	B	B
27th St./ Woods Blvd.	**Overall**	**5.3**	**6.9**	**B**	**A**	**4.7**	**6.1**	**A**	**A**	**6.5**	**8.5**	**B**	**A**	**4.1**	**5.3**	**A**	**A**	**12.7**	**16.5**	**B**	**B**	**13.7**	**17.8**	**B**	**B**
	NB	4.8	6.2	A	A	2.6	3.4	A	A	2.3	3.0	A	A	0.7	0.9	A	A	9.9	12.9	B	B	11.5	15.0	B	B
	SB	2.6	3.4	A	A	2.8	3.6	A	A	6.6	8.6	B	A	2.1	2.7	A	A	9.2	12.0	B	B	5.6	7.3	B	A
	EB	13.0	16.9	B	B	20.2	26.3	C	C	10.8	14.0	B	B	9.8	12.7	B	B	18.1	23.5	C	C	29.9	38.9	D	D
	WB	15.5	20.2	C	C	12.6	16.4	B	B	13.8	17.9	B	B	15.0	19.5	B	B	26.5	34.5	D	C	37.2	48.4	D	D

2.2.5 Pioneers Boulevard

Intersection delay studies were conducted at four (4) signalized intersections along this corridor. Table 20 summarizes the results of both the "before" and "after" intersection delay studies. Delay and LOS are reported for the overall intersection as well as for each individual approach for each of the three peak time periods. Delay study computations for each intersection are provided in Appendix B.

Results of the "after" intersection delay studies show each of the four intersections operating at LOS 'C' or better. Overall intersection delay at each location decreased during the PM Peak time period, with a corresponding increase in LOS at both the 40th Street and 48th Street intersections. LOS at all of the intersections remained unchanged during the AM Peak and Midday time periods.

Table 20: Intersection Delay Studies - Pioneers Boulevard

Intersection	Approach	AM Peak								Midday								PM Peak							
		"Before"				"After"				"Before"				"After"				"Before"				"After"			
		Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS
56th Street	**Overall**	**16.7**	**21.7**	**C**	**C**	**20.0**	**26.0**	**C**	**C**	**9.4**	**12.2**	**B**	**B**	**10.0**	**13.0**	**B**	**B**	**21.9**	**28.5**	**C**	**C**	**16.1**	**20.9**	**C**	**C**
	NB	12.3	16.0	B	B	20.1	26.1	C	C	6.9	9.0	B	A	7.4	9.6	B	A	26.8	34.8	D	C	15.2	19.8	C	B
	SB	11.5	15.0	B	B	11.3	14.7	B	B	3.8	4.9	A	A	4.7	6.1	A	A	9.8	12.7	B	B	7.4	9.6	B	A
	EB	27.7	36.0	D	D	27.3	35.5	D	D	22.5	29.3	C	C	21.5	28.0	C	C	43.8	56.9	E	E	33.9	44.1	D	D
	WB	24.7	32.1	C	C	22.1	28.7	C	C	15.4	20.0	C	C	16.0	20.8	C	C	22.6	29.4	C	C	24.8	32.2	C	C
48th Street	**Overall**	**12.3**	**16.0**	**B**	**B**	**14.6**	**19.0**	**B**	**B**	**9.1**	**11.8**	**B**	**B**	**9.5**	**12.4**	**B**	**B**	**16.9**	**22.0**	**C**	**C**	**11.6**	**15.1**	**B**	**B**
	NB	17.7	23.0	C	C	25.6	33.3	D	C	7.7	10.0	B	B	6.2	8.1	B	A	7.6	9.9	B	A	8.4	10.9	B	B
	SB	8.3	10.8	B	B	5.8	7.5	B	A	6.8	8.8	B	A	6.4	8.3	B	A	10.9	14.2	B	B	13.4	17.4	B	B
	EB	4.8	6.2	A	A	11.7	15.2	B	B	15.9	20.7	C	C	21.7	28.2	C	C	31.4	40.8	D	D	13.7	17.8	B	B
	WB	19.2	25.0	C	C	7.8	10.1	B	B	9.0	11.7	B	B	9.8	12.7	B	B	17.5	22.8	C	C	9.8	12.7	B	B
40th Street	**Overall**	**19.5**	**25.4**	**C**	**C**	**20.5**	**26.7**	**C**	**C**	**10.9**	**14.2**	**B**	**B**	**9.8**	**12.7**	**B**	**B**	**19.7**	**25.6**	**C**	**C**	**12.8**	**16.6**	**B**	**B**
	NB	32.8	42.6	D	D	33.6	43.7	D	D	15.8	20.5	C	C	11.2	14.6	B	B	21.0	27.3	C	C	18.0	23.4	C	C
	SB	8.5	11.1	B	B	10.0	13.0	B	B	11.0	14.3	B	B	10.4	13.5	B	B	26.5	34.5	D	C	13.8	17.9	B	B
	EB	12.1	15.7	B	B	19.7	25.6	C	C	10.6	13.8	B	B	11.7	15.2	B	B	10.8	14.0	B	B	8.3	10.8	B	B
	WB	14.5	18.9	B	B	11.8	15.3	B	B	5.6	7.3	B	A	6.1	7.9	B	A	16.9	22.0	C	C	10.0	13.0	B	B
33rd Street	**Overall**	**8.4**	**10.9**	**B**	**B**	**8.7**	**11.3**	**B**	**B**	**5.1**	**6.6**	**B**	**A**	**6.6**	**8.6**	**B**	**A**	**10.3**	**13.4**	**B**	**B**	**8.9**	**11.6**	**B**	**B**
	NB	17.1	22.2	C	C	6.8	8.8	B	A	6.0	7.8	B	A	5.4	7.0	B	A	4.8	6.2	A	A	15.4	20.0	C	C
	SB	16.4	21.3	C	C	11.8	15.3	B	B	5.7	7.4	B	A	13.4	17.4	B	B	15.4	20.0	C	C	13.8	17.9	B	B
	EB	5.7	7.4	B	A	10.5	13.7	B	B	6.3	8.2	B	A	3.7	4.8	A	A	7.2	9.4	B	A	6.7	8.7	B	A
	WB	2.6	3.4	A	A	7.6	9.9	B	A	3.6	4.7	A	A	5.1	6.6	B	A	12.0	15.6	B	B	1.7	2.2	A	A

2.2.6 Vine Street

Intersection delay studies were conducted at five (5) signalized intersections along this corridor. Table 21 summarizes the results of both the "before" and "after" intersection delay studies. Delay and LOS are reported for the overall intersection as well as for each individual approach for each of the three peak time periods. Delay study computations for each intersection are provided in Appendix B.

In general, study intersections along this corridor decreased in overall intersection delay during most time periods. Overall intersection delay decreased during all three time periods at the intersection of 33rd Street/Vine Street. "After" studies also indicate all study intersections operate at LOS 'C' or better, with the exception of 14th Street/Vine Street during the Midday time period. However, high intersection delay at the intersection of 14th Street/Vine Street during this time period is due primarily to the high volume of pedestrians crossing the intersection. Therefore, the amount of delay experienced by motorists at this intersection is affected by vehicle/pedestrian conflicts and not by high vehicle volumes and traffic signal timings. While conducting the intersection delay studies, general observations indicate that oftentimes, pedestrians do not obey the pedestrian signal indications nor do all pedestrians cross at the marked crosswalks that are provided. Both of these conditions result in additional delays to vehicular traffic and the potential for vehicle/pedestrian accidents.

Dual intersection delay studies were conducted at the intersection of 33rd Street/Vine Street for both the "before" and "after scenarios to determine the variability in delay resulting from collecting data on different days. Variability between the delay studies conducted on different days for both the "before" and "after" scenarios was less than four seconds of stopped delay per vehicle.

Table 21: Intersection Delay Studies - Vine Street

Intersection	Approach	AM Peak								Midday								PM Peak							
		"Before"				"After"				"Before"				"After"				"Before"				"After"			
		Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS	Stopped Delay (sec/veh)	Control Delay (sec/veh)	1994 HCM LOS	2000 HCM LOS
66th Street	**Overall**	**8.4**	**10.9**	**B**	**B**	**9.8**	**12.7**	**B**	**B**	**9.3**	**12.1**	**B**	**B**	**6.1**	**7.9**	**B**	**A**	**11.5**	**15.0**	**B**	**B**	**9.7**	**12.6**	**B**	**B**
	NB	10.0	13.0	B	B	7.0	9.1	B	A	11.8	15.3	B	B	4.3	5.6	A	A	16.8	21.8	C	C	8.5	11.1	B	B
	SB	4.2	5.5	A	A	9.7	12.6	B	B	7.2	9.4	B	A	5.0	6.5	A	A	4.3	5.6	A	A	9.4	12.2	B	B
	EB	6.9	9.0	B	A	6.9	9.0	B	A	10.0	13.0	B	B	10.0	13.0	B	B	11.9	15.5	B	B	11.6	15.1	B	B
	WB	10.4	13.5	B	B	14.4	18.7	B	B	6.4	8.3	B	A	5.5	7.2	B	A	9.3	12.1	B	B	8.5	11.1	B	B
Cotner Boulevard	**Overall**	**20.7**	**26.9**	**C**	**C**	**13.9**	**18.1**	**B**	**B**	**18.2**	**23.7**	**C**	**C**	**13.0**	**16.9**	**B**	**B**	**18.8**	**24.4**	**C**	**C**	**23.2**	**30.2**	**C**	**C**
	NB	27.2	35.4	D	D	22.6	29.4	C	C	20.8	27.0	C	C	13.6	17.7	B	B	22.6	29.4	C	C	26.6	34.6	D	C
	SB	11.3	14.7	B	B	8.8	11.4	B	B	19.1	24.8	C	C	11.9	15.5	B	B	19.5	25.4	C	C	21.7	28.2	C	C
	EB	22.8	29.6	C	C	22.5	29.3	C	C	15.1	19.6	C	B	14.6	19.0	B	B	13.4	17.4	B	B	16.3	21.2	C	C
	WB	26.6	34.6	D	C	12.0	15.6	B	B	17.7	23.0	C	C	11.5	15.0	B	B	22.4	29.1	C	C	32.4	42.1	D	D
56th Street	**Overall**	**11.9**	**15.5**	**B**	**B**	**11.0**	**14.3**	**B**	**B**	**5.1**	**6.6**	**B**	**A**	**8.4**	**10.9**	**B**	**B**	**15.7**	**20.4**	**C**	**C**	**15.3**	**19.9**	**C**	**B**
	NB	10.3	13.4	B	B	6.2	8.1	B	A	2.7	3.5	A	A	8.8	11.4	B	B	22.3	29.0	C	C	9.1	11.8	B	B
	SB	14.5	18.9	B	B	12.4	16.1	B	B	10.9	14.2	B	B	10.4	13.5	B	B	21.1	27.4	C	C	28.9	37.6	D	D
	EB	22.4	29.1	C	C	11.8	15.3	B	B	6.1	7.9	B	A	6.7	8.7	B	A	6.7	8.7	B	A	12.7	16.5	B	B
	WB	7.0	9.1	B	A	12.1	15.7	B	B	2.5	3.3	A	A	7.7	10.0	B	B	16.8	21.8	C	C	7.8	10.1	B	B
33rd Street #1[1]	**Overall**	**13.6**	**17.7**	**B**	**B**	**11.6**	**15.1**	**B**	**B**	**8.5**	**11.1**	**B**	**B**	**6.8**	**8.8**	**B**	**A**	**16.0**	**20.8**	**C**	**C**	**13.8**	**17.9**	**B**	**B**
	NB	22.3	29.0	C	C	21.2	27.6	C	C	11.7	15.2	B	B	16.3	21.2	C	C	13.9	18.1	B	B	17.5	22.8	C	C
	SB	26.0	33.8	D	C	15.6	20.3	C	C	11.6	15.1	B	B	9.6	12.5	B	B	21.4	27.8	C	C	16.9	22.0	C	C
	EB	9.0	11.7	B	B	9.9	12.9	B	B	7.2	9.4	B	A	2.8	3.6	A	A	11.3	14.7	B	B	10.1	13.1	B	B
	WB	6.8	8.8	B	A	6.1	7.9	B	A	3.6	4.7	A	A	5.3	6.9	B	A	18.7	24.3	C	C	15.7	20.4	C	C
33rd Street #2[1]	**Overall**	**15.9**	**20.7**	**C**	**C**	**15.5**	**20.2**	**C**	**C**	**10.7**	**13.9**	**B**	**B**	**7.8**	**10.1**	**B**	**B**	**17.9**	**23.3**	**C**	**C**	**16.0**	**20.8**	**C**	**C**
	NB	16.5	21.5	C	C	16.9	22.0	C	C	27.6	35.9	D	D	15.6	20.3	C	C	13.8	17.9	B	B	15.7	20.4	C	C
	SB	25.8	33.5	D	C	39.9	51.9	D	D	18.7	24.3	C	C	16.2	21.1	C	C	24.3	31.6	C	C	33.0	42.9	D	D
	EB	17.1	22.2	C	C	12.0	15.6	B	B	6.3	8.2	B	A	2.4	3.1	A	A	19.5	25.4	C	C	10.3	13.4	B	B
	WB	10.0	13.0	B	B	5.5	7.2	B	A	3.3	4.3	A	A	2.4	3.1	A	A	12.3	16.0	B	B	9.6	12.5	B	B
14th Street	**Overall**	**6.7**	**8.7**	**B**	**A**	**7.3**	**9.5**	**B**	**A**	**74.0**	**96.2**	**F**	**F**	**66.7**	**86.7**	**F**	**F**	**18.6**	**24.2**	**C**	**C**	**19.7**	**25.6**	**C**	**C**
	NB	5.6	7.3	B	A	6.5	8.5	B	A	5.6	7.3	B	A	0.8	1.0	A	A	4.5	5.9	A	A	1.9	2.5	A	A
	SB	6.2	8.1	B	A	10.5	13.7	B	B	6.2	8.1	B	A	131.3	170.7	F	F	33.2	43.2	D	D	36.5	47.5	D	D
	EB		0.0	-	-		0.0	-	-		0.0	-	-		0.0	-	-		0.0	-	-		0.0	-	-
	WB	7.1	9.2	B	A	4.4	5.7	A	A	7.1	9.2	B	A	4.1	5.3	A	A	11.4	14.8	B	B	4.4	5.7	A	A

2.3 Analysis of Intersection Improvements

Based on the results of the intersection delay studies conducted for each corridor, intersections were identified where individual approaches of the intersection operate at LOS 'D' or worse. These intersections were further analyzed to determine if traffic operations for the individual approaches and/or the overall intersection would benefit from minor improvements in lane configuration (i.e.-adding right-turn or left-turn lanes) and/or signal phasing (i.e.-adding or removing permitted/protected phasing). Consideration was also given as to whether any minor improvements would be physically and economically practical and/or feasible. Analyses of potential improvements were performed using Synchro, a nationally accepted computer software package incorporating the methodologies of the 2000 HCM.

North 27th Street/Holdrege Street

This intersection currently operates at or near LOS 'D' during both the AM and PM Peak time periods. The northbound and southbound approaches operate at or near LOS 'D' during the AM Peak, and the eastbound and westbound approaches operate at or near LOS 'D' during all three peak time periods.

Analysis of the intersection using Synchro indicates that the northbound and southbound approaches could benefit from the addition of right-turn lanes. Computer analysis of the AM Peak time period, which experiences the highest level of delay of the three peak time periods, indicates that with these two right-turn lanes, an improvement in overall delay from 29.6 veh/sec to 25.4 veh/sec, with a corresponding improvement in the volume-to-capacity ratio (V/C) from 0.84 to 0.76 would result. The southbound approach improves from 24.9 veh/sec (LOS 'C') to 16.0 sec/veh (LOS 'B') and the northbound approach improves from 15.9 veh/sec to 12.6 veh/sec. However, existing right-of-way constraints near both the northbound and southbound approaches make these improvements difficult to implement.

Both the eastbound and westbound approaches also experience relatively high average delay and decreased LOS. However, decreased efficiency in traffic operations are primarily due to unbalanced lane utilization and "bottlenecks" created by merging lanes of traffic downstream of both approaches.

North 27th Street/Superior Street

This intersection is characterized by high traffic volumes, especially during the three peak time periods, dual left-turn lanes on the northbound, eastbound and westbound approaches with protected signal phasing and exclusive right-turn lanes on the eastbound and westbound approaches. Therefore, very few possibilities for minor improvements exist based on these existing characteristics.

North 48th Street/Vine Street

"After" intersection delay studies indicate that this intersection operates relatively efficiently (LOS 'C') during both the AM Peak and Midday time periods. However, the overall intersection operates at LOS 'D' during the PM Peak time period, with the eastbound and westbound approaches operating at LOS 'D' or worse. To improve operations for both of these approaches and the overall intersection, additional right-turn lanes are suggested for the northbound, eastbound and westbound approaches. Synchro analysis indicates that these improvements would decrease overall delay during the PM Peak from 37.2 sec/veh to 30.8 sec/veh, with the V/C ratio decreasing from 0.87 to 0.79. However, due to close proximity of businesses to each of these approaches, careful consideration should be given to the assessment of the potential benefits of these improvements versus the cost of acquiring the necessary right-of-way required for implementation.

North 48^th Street/Leighton Avenue

Although this intersection operates fairly efficiently during all three peak time periods, the westbound approach experiences relatively high average delay and low LOS. Currently, the westbound approach provides only one lane of traffic to service all westbound vehicles. The addition of a left-turn lane is recommended to allow more vehicles to be serviced under the current signal timing and phasing of the intersection. By providing this additional lane, analysis of the intersection for the AM Peak indicates that average delay for the westbound approach would decrease from 55.3 sec/veh (LOS 'E') to 42.9 sec/veh (LOS 'D'). With this additional lane, the overall intersection delay would improve from 30.9 sec/veh to 28.3 sec/veh.

North 70^th Street/Adams Street

This intersection operates at LOS 'C' or better during all three time periods. However, the eastbound approach operates at LOS 'D' during the PM Peak. An additional lane for left-turning vehicles is recommended for the eastbound approach to alleviate vehicle delay and improve safety at the intersection. According to Synchro analysis, the addition of an eastbound left-turn lane would improve average eastbound approach delay during the PM Peak from 27.2 sec/veh to 19.8 sec/veh and overall intersection delay from 15.5 sec/veh to 14.0 sec/veh. V/C ratio would also improve from 0.71 to 0.67. However, difficulties may arise in acquiring the necessary right-of-way based on the close proximity of the approach to a nearby gas station/convenience store.

Nebraska Highway 2/Old Cheney Road

At this intersection, the eastbound approach on Old Cheney Road experiences significant delay and decreased LOS during both the AM Peak and Midday time periods. At present, Old Cheney Road is a two-lane roadway north/east of Nebraska Highway 2. Future construction schedules indicate that this roadway will be widened to accommodate two lanes of traffic in each direction. Currently, the eastbound approach on Old Cheney Road provides a left-turn lane, a through lane and a right-turn lane. With the completion of construction on Old Cheney Road north of Nebraska Highway 2, it is recommended that the eastbound approach be converted from the existing configuration to a left-turn lane, through lane and a shared through/right-turn lane. According to Synchro, this would improve average delay for the approach from 70.0 sec/veh (LOS 'E') to 52.7 sec/veh (LOS 'D') during the AM Peak time period. Also, due a relatively high volume of vehicles making a southbound left-turn from Highway 2 onto Old Cheney Road, permitted/protected phasing is also suggested for the southbound approach on Nebraska Highway 2.

56th Street/Vine Street

Intersection delay studies conducted at this intersection indicate that the overall intersection operates at LOS 'C' or better. However, the studies also indicated that the westbound approach operates at LOS 'D' during the PM Peak time period. Future, scheduled improvements at this intersection, which include adding eastbound and westbound left-turn lanes, are scheduled to be complete by the end of year 2001. Based on planned improvements at the intersection, which will have a positive effect on traffic operations, no other minor improvements are being recommended at this time.

33rd Street/Vine Street

This intersection is located within a residential area near Hartley Elementary School. Intersection delay studies indicate that this intersection operates at LOS 'C' or better during all three time periods. However, the southbound approach does experience increased averaged delay and diminished LOS during both the AM and PM Peak time periods. Permitted/protected phasing is suggested for both the northbound and southbound approaches. Although computer analysis does not indicate any significant improvement in delay for the intersection or either of the approaches, the change in phasing has the potential to increase safety for both motorists and pedestrians utilizing the intersection.

Several other intersections with approaches operating at LOS 'D' or worse were also identified. However, further analysis and investigation of these locations did not reveal any potential minor improvements that would benefit or improve the operation of the intersection.

3.0 ADDITIONAL DATA COLLECTION ACTIVITIES

In addition to collecting travel time and intersection delay data for the purpose of monitoring arterial streets and optimizing signal timing plans, as discussed in Sections 1 and 2, traffic volume data was collected for use in Task 2 as well as for the general use by City staff. These data collection activities included conducting 6-hour turning movement counts and pedestrian/bicycle counts at 70 signalized intersections to obtain peak hour traffic volumes during the AM Peak, Midday and PM Peak time periods. Forty-eight-hour mechanical counts ("tube counts") were conducted at 50 locations to obtain average daily traffic volumes. These locations are illustrated in Figures 5 and 6.

Results of these data collection activities were submitted to City staff as part of Phase I of this contract.

FIGURE 5 TURNING MOVEMENT COUNT LOCATIONS

FIGURE 6 MECHANICAL COUNT LOCATIONS

4.0 SIGNAL TIMING

4.1 Introduction

The goal of this task was to develop optimum signal timings and progression alternates for each of the six study corridors illustrated in Figure 2. This included the evaluation of the existing signal timing plans in order to make recommendations for improvements to the cycle lengths, phase sequences, and phase splits to improve mobility through the corridors.

In order to provide efficient signal timing coordination, it is important, at times, to include intersections that are not part of the corridor but are adjacent to the study corridor(s). A focus area analysis was conducted prior to the initiation of the signal timing task. The purpose of the focus area analysis was to identify intersections that are not along the study corridors but are in close enough proximity to them, that they impact, or are impacted by, traffic and signal operations along a corridor. The criteria developed for the focus area analysis, described in the "Focus Area Analysis Report", January 2000, included:

- Traffic flow characteristics,
- Proximity of intersections to each other,
- System-wide coordination considerations, and
- Sub-system analysis.

Utilizing the above criteria, it was determined that Pioneers Boulevard between Nebraska Highway 2 and 56th Street should be included in the Nebraska Highway 2 corridor analysis, resulting in the sixth corridor. The inclusion of Pioneers Boulevard into the analysis would evaluate, and provide recommendations for, the merging of westbound vehicles from Pioneers Boulevard onto Highway 2 in a safe and efficient manner. The intersections of 56th Street/Old Cheney Road, 48th Street/Old Cheney and 27th Street/Woods Boulevard were also included in the analysis of the Nebraska Highway 2 corridor.

Table 22 lists the six corridors studied and their corresponding boundaries.

Table 22: Analysis Corridors

Analysis Corridor	Limits
27th Street	Between "O" Street and Interstate 80 (I-80)
48th Street	Between "O" Street and Superior Street
70th Street	Between "O" Street Havelock Avenue
Vine Street	Between 70th Street and 14th Street
Pioneers Boulevard	Between 56th Street and 33rd Street
Nebraska Highway 2	Between Old Cheney Road and Van Dorn Street[1]

1 Nebraska Highway 2 corridor also includes the intersections of 56th Street/Old Cheney Road, 48th Street/Old Cheney Road and 27th Street/Woods Boulevard

4.2 Existing Conditions

AM Peak, Midday, and PM Peak hour turning movement counts, lane configurations, speed limits, and signal timing information were collected as part of the data collection effort for existing conditions. This information was used to update the City's existing traffic model (Synchro).

4.3 Analysis

Signal timing analyses were performed using Synchro, a nationally accepted computer software package. This software has been used widely to perform capacity analyses and develop optimized signal timing plans, including signal timing splits, cycle lengths, offsets, and lead-lag phasing sequences.

Using the new turning movement data collected by The Schemmer Associates (TSA) as well as existing data from the City of Lincoln Public Works and Utilities Department, optimal operating conditions were then evaluated in a three-step process:

Step 1. Existing Cycle and Existing Phase Sequence

The operating conditions under the existing signal timing and revised turning movement volumes were observed.

Step 2. Optimized Cycle and Existing Phase Sequence

In order to begin the analysis process, a sub-system evaluation was first conducted for each analysis corridor. This analysis is based on factors such as the distance between intersections, cross street traffic volumes, and other coordinated corridors within the City of Lincoln signal system. Figure 7 illustrates the sub-system boundaries for the six analysis corridors.

For each corridor/sub-system, cycle lengths between 50 and 150 seconds were analyzed. In choosing the most optimum cycle length, the following factors were taken into consideration:

1. System-wide coordination
2. Proximity of study corridors to other major corridors in the system
3. Intersection turning movement volumes
4. Individual intersection delay and LOS
5. Approach delay per movement for each intersection

In order to provide an efficient flow of traffic, it is important to provide a cycle length that would provide sufficient green time to be capable of serving all movements. However, long cycle lengths generally result in high delays for the minor approaches. Consideration is given to all of the above factors in determining the optimum cycle length.

FIGURE 7: SUB-SYSTEM ANALYSIS

System-wide coordination is accomplished by using a similar cycle length throughout the system. In the analysis, if the optimal cycle lengths chosen were within a few seconds of the existing cycle lengths, and the optimization did not make a significant improvement to the intersection operations, the existing cycle length was retained. Comparisons were made between existing and proposed signal timing plans using various measures of effectiveness (MOEs). Examples of MOEs include bandwidth lengths in both directions, flow diagrams, and approach delays. Table 23 summarizes the "before" and "after" cycle lengths for each of the sub-systems.

Step 3. Optimized Cycle and Optimized Phase Sequence and Offsets

The final step in the analysis process was to calculate the optimum signal timing splits to provide sufficient green time for each movement so that the maximum number of the vehicles would be served. In addition, offsets were optimized to provide the most efficient coordination with the widest bandwidth.

The following is a brief description of each study corridor and the analysis procedure.

North 27^th^ Street

The optimization of signal timings for South 27^th^ Street was conducted as part of the previous phase of this project. Due to the high vehicular trips along 27^th^ Street between Old Cheney and Superior Street, and its importance to the City of Lincoln's overall traffic flow, North 27^th^ Street was added to the list of corridors to be analyzed as part of this phase of the project. The intersection of 27^th^ Street at "O" Street operates as part of the "O" Street signal system. As a result, the southern-most intersection of the North 27^th^ Street sub-system was chosen to be 27^th^/"O" Street. Due to traffic flow pattern changes during all three study periods and the large distance between intersections (approximately 4,000 feet between the intersections of 27^th^/Fair Streets and 27^th^ Street/Cornhusker Highway), Cornhusker Highway was chosen to be a natural breaking point. Similarly, due to the large distance between the intersections of 27^th^/Fairfield Streets and 27^th^/Superior Streets (approximately 3,500 feet), the intersections north of Superior Street serve as a separate sub-system.

North 48^th^ Street

Similar to the 27^th^ Street corridor, traffic signal coordination continuity was one of the reasons to continue the coordination along 48^th^ Street north of "O" Street. With the inclusion of North 48^th^ Street, this continuity is possible. Due to the relationship between North 48^th^ Street and the Holdrege Street and 33^rd^ Street corridors, special attention was given to the effects this analysis had on these previously analyzed corridors. Due to the large distance between the intersections of 48^th^/Holdrege Streets and 48^th^ Street/Leighton Avenue (approximately 2,650 feet), this area was chosen to be a natural break point. The intersections of 48^th^/Superior Streets and 48^th^ Street/Cornhusker Highway operate under separate systems and were not included in the sub-system north of Leighton Avenue.

Table 23: "Before" & "After" Sub-system Signal Timing Plan Cycle Lengths

Corridor	Sub-system	Intersections [2]	No. of Intersections	Cycle Length [1] AM Peak Before	AM Peak After	Midday Before	Midday After	PM Peak Before	PM Peak After
27th Street	A	Between Kensington Dr. and Superior St.	4	120	120	100	100	120	120
	B	Between Fairfield St. and Cornhusker Hwy.	3	120	120	100	100	120	120
	C	Between Fair St. and "O" St.	6	120	120	100	100	120	120
48th Street	A	At Superior St.	1	Free	Free	Free	Free	Free	Free
	B	At Cornhusker Hwy.	1	120	120	100	100	60	120
	C	Between Fremont St. and Leighton Ave.	5	120	120	100	100	60	120
	D	Between Holdrege St. and "O" St.	5	120	120	100	100	60	120
70th Street	A	Between Havelock Ave. and "O" St.	9	60	60	60/100 [3]	50	60	120
Vine Street	A	Between 14th St. and 33rd St.	6	120	120	60/100 [3]	100	120	120
	B	Between 45th St. and 70th St.	7	120	120	60/100 [3]	100	120	120
Pioneers Boulevard	A	Between 33rd St. and 56th St.	6	120	120	75	75	120	120
Nebraska Highway 2	A	Between Van Dorn St. and Old Cheney Rd.	11	120	120	60/100 [3]	60 / 100 [4]	120	120

Notes:
1 The cycle lengths presented, represent sub-system cycle lengths. Half-cycling was used at some intersections, during some time periods, to increase intersection efficiency (for "before" and "after" conditions). Pedestrian signals were all set to operate with a 60 second cycle length.
2 "O" Street operates as a separate sub-system and as a result, cycle lengths, offsets and "O" Street timings were not modified.
3 Prior to implementation of new signal timings, intersections along this corridor operated at various cycle lengths.
4 The intersections of 9th/Van Dorn Streets and 10th/Van Dorn Streets operate with a 60-second cycle length as part of the 9th/10th Street sub-system. The remaining intersections along the Highway 2 corridor operate with a 100-second cycle length.

North 70th Street

The 70th Street Corridor is the eastern-most corridor that will be analyzed for signal timing as part of this phase of the project. This corridor has, and will continue to experience traffic growth due to growth and expansion of the City. As a result, it was important to conduct a thorough analysis of this corridor. The 70th Street corridor was not broken into separate sub-systems. Rather, it was optimized as one single system. The signal timing plans for this corridor were developed following the development of the signal timing plans for the North 27th, North 48th and Vine Street corridors.

Vine Street

Vine Street is a major east/west corridor connecting the three north/south study corridors (27th, 48th, and 70th Street Corridors). In analyzing these corridors, the 27th Street corridor was analyzed first, since it has higher traffic volumes than the other corridors. Once the timings along 27th Street had been developed, signal timing plans for the Vine Street corridor were developed. Due to the large distance between 33rd Street and 45th Street, the Vine Street corridor was divided into two sub-systems between these two intersections

Nebraska Highway 2 and Pioneers Boulevard

During the AM Peak, peak traffic flow is in the westbound direction. In addition, high northbound-to-westbound left-turn volumes exist at the intersections of 27thStreet/Hwy 2 and 40th Street/Hwy 2. These high volumes result from the densely populated residential neighborhoods south of Highway 2 and the large employment centers in north and northwest Lincoln, including Downtown Lincoln. In developing the new signal timings along Highway 2, these high left-turn volumes played an important role in the analysis. In addition, it was important to develop a signal timing pattern such that vehicles merging from Pioneers Boulevard onto Highway 2 do so safely and do not conflict with platoons of vehicles traveling westbound along Highway 2.

Similar travel patterns are evident during the Midday time period, however, at lesser levels. During the PM Peak, the reverse commute occurs. That is, vehicles travel from Downtown Lincoln to the residential neighborhoods in the south. This is evident in the high eastbound-to-southbound right-turn volumes from Highway 2 onto 27th and 40th Streets.

Due to the close proximity of the intersections of 48th Street/Old Cheney Road, 56th Street/Old Cheney Road and 27th Street/Woods Boulevard to the Nebraska Highway 2 corridor, signal operations at these intersections were also included in this analysis. Neither of these two corridors were divided into smaller subsystems.

4.3.1 Signal Timing Implementation

The recommended signal timing modifications were presented to City of Lincoln staff for approval and implementation. After implementation of the new signal timing information, field reviews were conducted. Using information and comments from field reviews, refined (final) AM Peak, Midday, and PM Peak signal timing/progression plans were developed which included cycle length, splits, offsets, and time-space diagrams. A summary of the signal timing changes made to the six corridors is included in Appendix C. These summaries include signal timing split, cycle length and offset changes for each intersection.

The analysis conducted in this project did not include coordinated signal timings for any of the several, signalized, mid-block pedestrian crossings. The City of Lincoln currently operates these pedestrian signals in actuated mode, such that pedestrian demand, registered by pedestrian pushbutton calls, cause the signal to immediately transition from serving vehicles to serving the pedestrian movement. Such interruptions in arterial flow are entirely random, occurring without regard for the approach of a platoon of vehicles progressing along the corridor.

While this immediate pedestrian service does satisfy pedestrian needs, it can cause disruption to the coordinated traffic flow on the arterial street. Depending on how frequent pedestrians appear, it can provide a significant and continuing breakdown of traffic flow. In order to avoid such breakdowns in flow, the coordinated timing plan can, instead, include these signalized pedestrian crossings so that platoons of vehicles are progressed through these minor "intersections", taking priority over the pedestrians waiting to cross.

If the guaranteed window of passage for vehicles traversing through these crossings was made too long, then pedestrians would have the inclination to jaywalk. Therefore, this guaranteed window of passage for vehicles should be short and varied at each location depending on the vehicular and pedestrian demands. With this setting, pedestrians are likely to be witnessing a congested roadway during the portions of the cycle when the pedestrian service is temporarily prevented. If numerous vehicles and/or closely approaching platoons are present, there should be little inclination for pedestrians to attempt jaywalking. Even if only the first portions of platoons are guaranteed passage, this should improve traffic operations and safety. If an entire platoon of approaching vehicles is stopped in or near the dilemma zone (which would result if there is no vehicle detection on the arterial approaching the signalized pedestrian crossings), there will be increased incidence of rear-end accidents as following vehicles fail to properly space themselves and stop safely.

It should be noted that it is important to implement a consistent signal timing setting at all signalized pedestrian crossings throughout the City. By doing so, the timing plans will not violate pedestrian and driver expectations, reducing the probability of an accident.

5.0 SIGNAL OPERATION OPPORTUNITIES DURING OFF-PEAK HOURS

5.1 Introduction

There are a variety of alternatives in traffic signal operation. For example, during peak period conditions, due to heavier traffic volumes on the roadways, traffic signals are generally set to coordinated operation. The following is a list of modes of operation available in operating signalized intersections during various periods of the day.

1. <u>Coordinated Operation</u>: The predominant goal of coordination is to service the greatest number of vehicles through a series of intersections (system) with the fewest stops. Ideally, every vehicle entering the system could proceed through the system without stopping. However, this is not possible, even in well-spaced, well-designed systems. Coordinated timing can be used to provide for the minimum number of stops and/or delays through intersections that are fully actuated, semi-actuated or pre-timed.

2. <u>Fully-Actuated / "Free" Operation:</u> A fully actuated intersection is one that has vehicle detection on every approach. A fully actuated intersection with "free" operation refers to an intersection signal timing plan operating based on actual demand that is detected by vehicle detectors, either in the roadway or via cameras installed overhead.

3. <u>Semi-Actuated Operation:</u> A semi-actuated intersection generally has vehicle detection on the minor-street approaches. In semi-actuated operation, the major movement is continuously served until the minor movement requests to be served (via vehicle detectors). Once this request has been detected, the minor movement is served and then the signal resumes normal operation (serving the major movement).

4. <u>Pre-Timed Operation:</u> An intersection without vehicle detection is operated with pre-timed signal timing plans. The timing plans at these intersections are based on traffic counts collected on a typical day.

5. <u>Flashing Operation:</u> Two different flashing operations exist.

   a. *Yellow/red flashing operation*: The major street approach is provided with a flashing yellow indication and the minor street approach receives a flashing red indication. Some jurisdictions around the country utilize this operation during late-night hours to reduce vehicular delays and save on energy consumption.

   b. *Red/red flashing operation*: All approaches receive flashing red indications. This operation is also used during late night hours by some jurisdictions across the country. A red/red flashing operation is also sometimes utilized at intersections near fire stations (when a fire personnel vehicle is entering or exiting the fire station) or when the intersection is malfunctioning.

The City of Lincoln has been updating its signal timing plans during the peak periods (AM, Midday, and PM). In order to reduce vehicle delays and increase safety during the late-night, low-volume hours, the City has been investigating the implementation of an alternate late night timing plan. Currently, the City is utilizing free operation and reduced cycle lengths at some intersections. During low volume time periods (usually between 10:00 p.m. and 6:00 a.m.), there are a number of methodologies available to provide efficient movement of vehicles through intersections. This chapter summarizes the results of a study performed to identify a set of guidelines for alternative operation of signalized intersections during these late night hours and/or during low volume, off-peak time periods.

The remainder of this chapter is organized as follows:

Section 5.2 Literature Review: In order to develop a set of recommendations, various articles and previous research studies were analyzed. In addition, various jurisdictions across the country were contacted to better understand their late night, low volume signal timing methodologies.

Section 5.3 State of Practice for Late Night Operation: A review of existing standards in traffic signal operation during late night/low volume hours.

Section 5.4 Guidelines: Proposed guidelines for operation in the City of Lincoln.

5.2 Literature Review

Articles studied as part of this analysis were:

1. Guideline for the Use of Flashing Operation at Signalized Intersection, Kent C. Kacier, H. Gene Hawkins, Jr., Robert J. Benz, and Michael E. Obermeyer. ITE Journal, October 1995.

2. Issues in Flashing Operation for Malfunctioning Traffic Signals. Peter S. Parsonson and David J. Walker. ITE Journal, September 1992.

3. Relative Accident Impacts of Traffic Control Strategies During Low-Volume Night-Time Periods, James C. Barbaresso. ITE Journal, August 1987.

4. A Case Study of the Accident Impact of Flashing Signal Operations Along Roadways, Mathew J. Gaberty II and James C. Barbaresso. ITE Journal, July 1987.

Due to the fact that all of the articles found on this subject are not recent, other public agencies were contacted to better understand other currently used procedures for late night traffic signal operation. The following jurisdictions were contacted:

City of Omaha, Nebraska
City of Irvine, California
City of Rancho Cucamonga, California
City of San Francisco, California
Miami-Dade County, Florida
Montgomery County, Ohio

5.3 State of Practice for Late Night Operation

Currently, there is no widely accepted guideline for implementing late-night/low-volume traffic signal operation; therefore, the decision to implement a specific mode of operation varies widely between jurisdictions. The *Manual on Uniform Traffic Control Devices, Millennium Edition* (MUTCD 2000) does not contain any mention of appropriate times or traffic volumes to use a specific mode of operation.

In providing signal timing operation during late-night, low-volume hours, there are several operation methodologies available. Table 24 presents a list of five different modes of signal operation available and the advantages and disadvantages of each type of operation

5.3.1 Coordinated Operation

Midday signal timing plans were developed as part of the signal timing project for the City of Lincoln by The Schemmer Associates and Meyer, Mohaddes Associates. These timing plans utilize a shorter cycle length at some locations than those developed for the AM and PM Peak period conditions. The shorter cycle lengths were used at locations in which lower traffic volumes are present during the Midday hours of operation than the AM and PM Peak periods. Similarly, during the late night hours, signal timing plans with shorter cycle lengths can be developed to meet lower vehicular demands and reduce delays. However, it should be noted that in developing the signal timing plans and cycle length for the late night period, it is important that pedestrian minimum clearance times are met, especially at intersections that do not have pedestrian push buttons. The corridor or sub-system's cycle length should be based on the critical intersection's pedestrian minimum clearance times.

An advantage in providing coordination along corridors during late night hours is that lower vehicle delays will be experienced by drivers along major streets. This is especially true on routes with high truck volumes. However, delays to the minor movements are possible. This is due to the coordinated phase needing to meet their minimum timing requirements (coordination timing offset / force-off) before serving the minor street movements. This can lead to frustration of drivers on the minor streets.

5.3.2 Free Operation

In operating a signalized intersection with free operation, the synch phases are set to receive the green phase. Generally, these are the major movements. Once a side street or turning movement call has been received by the detectors, the synch phases will complete serving the minimum required times (pedestrian time, if any + yellow + all red, if any) and serve the minor movements. Once the minor movements have been served, the signal will return and serve the synch phase. Generally, operating intersections with free operation at semi- or fully-actuated intersections result in lower delays and a safer operation than utilizing flashing operation.

Table 24: Traffic Signal Low-Volume / Late-Night Operation Comparison

<table>
<tr><th colspan="2">Operation Mode</th><th>Method of Operation</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td rowspan="2">Coordinated Operation</td><td>1a. Normal peak period coordination pattern (possibly midday plan)</td><td>• Similar to peak period operation.</td><td>• Signal coordination
• Requires no main street detectors.</td><td>• Drivers on the minor approaches experience what they perceive to be excessively high delays.
• Results in driver frustration.</td></tr>
<tr><td>1b. Modified coordination pattern with shorter cycle length</td><td>• Shorter cycle length due to lower volumes.
• Larger yield window (request for green time) for the minor approaches.</td><td>• Will preserve some signal coordination
• Requires no main street detectors.</td><td>• Drivers on the minor approaches will experience some delay.</td></tr>
<tr><td colspan="2">2. Free operation</td><td>• Fully actuated operation.</td><td>• This operation will allow for quicker service of a vehicle once detected, resulting in lower traffic delays</td><td>• Must have vehicle detection on all approaches</td></tr>
</table>

Table 24 - Traffic Signal Low-Volume / Late-Night Operation Comparison (continued)

Operation Mode		Method of Operation	Advantages	Disadvantages
Flashing Operation	3a. Yellow/red flashing operation.	• Major street approaches operate with flashing yellow. • Minor street approaches operate with flashing red. • Protected left turn phases operate with flashing red arrow.	• Simulation studies have shown that this operation produces the least vehicular delays.	• Studies have shown that accident rates (especially right angle accidents) have risen at intersections that are prone to accidents during normal operation. • Vehicles approaching an intersection from the minor street approach can mistakenly assume all approaches operate with flashing red.
Flashing Operation	3b. Red/red flashing operation.	• All approaches operate with flashing red.	• Can be used as a method of "speed control". Vehicles will be forced to stop at all signalized intersections with this mode of operation.	• Studies have shown that accident rates (especially right angle accidents) have risen at intersections that are prone to accidents during normal operation. • Possible increase in the number of rear-end collisions. • Major movements will experience some delay due to stop-and-go operation.
4. Rest in red operation		• All approaches operate with a solid red. • Approach is served on a first come first serve basis once a vehicle has been detected. • Operates best if advance detectors are available.	• Can be used as a "speed control signal". The advance loops will not be utilized. Vehicle detection will be serviced by the stop bar detectors only, forcing the vehicle to stop at the intersection.	• Must have vehicle detection on all approaches. Advance detectors are needed for optimum operation. • Local drivers approaching an intersection expect immediate service and may not slow down as they approach the intersection. If immediate green is not granted (due to a service request on another approach) the vehicle might go through the red signal, resulting in a hazardous situation.

5.3.3 Flashing Operation

For flashing operation, the national MUTCD 2000 (Section 4K.2) defines the signal as "a highway traffic signal with one or more signal sections that operates in flashing mode. It can provide traffic control when used as an intersection control beacon or warning in alternative uses". It further states:

> Application of intersection control beacon indication shall be limited to the following:
>
> a. Yellow on one route (normally the major roadway) and red for the remaining approaches.
> b. Red for all approaches (if the warrant for a multi-way STOP is satisfied).
>
> Flashing yellow indications shall not face conflicting vehicular approaches.

The FHWA *Traffic Control Devices Handbook* (TDCH) states "Flashing yellow/red may be appropriate at simple, four-legged or three-legged intersections where the minor-street drivers have an unrestricted view of approaching main street traffic, and the traffic volumes are low."

There are several factors that should be considered when applying flashing operation. Some of these are: traffic volume, traffic volume as a percentage of signal warrant, time of day, accidents and day of the week. Although flashing operation is used, few agencies have evaluated its effectiveness. The following is a summary of findings from reviewing available literature and discussions with other jurisdictions across the country.

- The basis for selecting the mode of flashing operation (yellow/red or red/red) varies among agencies. Factors often considered by agencies in selection flashing mode are volumes, volume to capacity (v/c) ratios, accident history, consistency with other flashing signals, geometrics and sight distance, speed, and engineering judgment. Due to possible incorrect driver perception, it is not recommended that intersections operate with yellow/red operation. If flashing operation is implemented, red/red operation should be deployed.

- Some agencies delay the start of flashing operation on Thursday through Saturday night one-hour after nightclubs have closed.

- If side street visibility is good, the signal can be flashed during periods of time when the anticipated volume of traffic is low and when that volume can be more efficiently served by a flashing, rather than a cycling operation.

- If the side street visibility is marginal and requires side street drivers facing a flashing red display to pull up past the stop bar to achieve good visibility, yet not into the main street lanes, flashing should be reserved for periods of extremely low traffic flow.

- If side street drivers facing a flashing red display must pull into the main street lanes to see main street traffic, flashing operation is not recommended and should be reserved for signal malfunction and emergency pre-emption only.

- If a check of records reveals that a flashing operation has resulted in an increase of more than two accidents during the late night hours, that signal should be taken out of scheduled flash.

- Flashing operation is not recommended at intersections with dual left-turn lanes.

Through simulation studies conducted by various agencies, it has been found that flashing operation is beneficial in generally reducing vehicular delays at signalized, non-actuated intersections during the late night hours. In addition, flashing operation has shown to reduce electric energy consumption during the same late night hours. A typical intersection with four approaches, permissive left-turn movements and three vehicle signals per approach (assuming three section heads per signal) has a total of 36 signal heads (lamps). With two pedestrian signal heads per direction (total 8 pedestrian heads per intersection), a typical intersection would consume 5.34 kW of energy per hour (36 vehicle lamps on at any one time x 135 watts per lamp + 8 pedestrian lamps on at any one time x 60 watts per lamp). During the hours of 12AM and 5AM, the energy consumption would be approximately 812 kW per month. If the same intersection was to operate under flashing mode, pedestrian heads would be turned off and only half of the vehicle signal heads would be on at any one time. With flashing operation, 18 vehicle lamps will be on at any one time (total 36 signal heads at 50% on at any one time due to flashing operation). This will result in an energy consumption of 2.43 kW per hour (18 lamps x 135 watts per lamp). During the flashing hours of 12AM and 5AM, the energy consumption would be approximately 370 kW per month. The total energy savings for five hours would be approximately 442 kW per month. With an average cost of $0.05 per kW, the total cost savings would be approximately $22 per month, per intersection ($265 per year, per intersection).

From reviewing available literature and from discussions with various agencies, flashing operation has been found to have negative impacts. Some of the negative impacts are:

- Right-angle accidents were significantly higher with flashing signal operations.

- A motorist facing a flashing red display may assume the opposing traffic signal to also display a flashing red, although a flashing yellow could be displayed.

- Some motorists may not know how to react to a flashing yellow and may stop, increasing the risk of rear-end crashes.

- During flashing operation, pedestrian beacons are turned off. Pedestrians would then need to find an acceptable gap in traffic and cross the street. This results in a hazardous situation especially on wider crossings.

- On one-way streets, such as those in the downtown Lincoln area, pedestrians walking the opposite direction of the flow of traffic, may be unaware of the type of intersection operation. With pedestrian beacons turned off (which occurs during flashing mode) and no vehicular signal head, pedestrians are unaware of the operation of the intersection.

- A 1998 study conducted in San Francisco, California by the San Francisco Department of Parking and Traffic showed that even though city-wide overall collisions had increased, there was a 25 percent decrease in the number of injury accidents at intersections in which flashing operation had been removed during the late night periods.

5.3.4 Rest in Red Operation

Within the rest in red operation, there are two modes of operation. Both modes of operation require full actuation at the intersection and under both modes of operation, all approaches operate with a solid red and an approach is served on a first come, first serve basis.

One mode of operation will require advanced detectors in addition to the stop bar detectors. Upon the detection of a vehicle by the advanced detector(s), the movement is immediately served so that the vehicle experiences minimal delay. The second mode of operation is set such that a movement is served only once vehicles are detected by the stop bar detectors. This design will ensure that vehicles slow on intersection approach. The purpose of the second mode of rest in red operation is not necessary to reduce delay, but to discourage vehicles from traveling at unsafe speeds.

The disadvantage of this type of operation is that all approaches to the intersection must have vehicle detection, and advance detectors are needed for optimum operation. In addition, drivers approaching an intersection begin expecting immediate service under mode one as drivers learn the general operation of the signal and would not slow down as they approach the intersection. If immediate green is not granted (due to a service request on another approach first) the vehicle might go through a red light, increasing the possibility of an accident.

5.4 Proposed Guidelines

5.4.1 Late Hour / Low Volume Timing Period Determination

The nighttime period is characterized by a heavy drop in traffic volumes to the level where operating the signals in coordinated mode is no longer as efficient. Although the typical nighttime period is from 10 p.m. to 6 a.m., this is not always the case. In determining the exact late night hours in which alternative traffic operation modes should be considered, a list of criterion has been developed. It should be noted that due to the unique characteristics of each corridor, engineering judgment should also be utilized in developing the exact time period in which the following modes of operation should be implemented.

Flashing Operation

LOS 'B' was chosen as the threshold intersection operation LOS because it is defined by the *Highway Capacity Manual* (HCM) as "stable operation / minimal delays: an occasional approach phase is fully utilized. Many drivers begin to feel somewhat restricted within platoons of vehicles".

Through examination of various major corridors in Lincoln, volumes that represent approximately 25% of the PM Peak period volumes at a critical intersection along a sub-system result in the reduction of delay at the intersection to a low LOS 'B' (close to LOS 'A'). Due to the nature in which intersections operate under LOS 'B' or better and the arrival pattern of vehicles, developing platoons of vehicles for coordination is difficult. As a result, during these low volume periods, signal timing coordination would not result in much of a benefit. In addition, flashing signal operation can only be safe at low volume intersections. The operation of an intersection at 25 percent of its PM Peak volume does result in lower turning movement volumes such that safety would not be compromised from the standpoint of traffic volume. However, there are other considerations (i.e. sight distance) that should also be considered in developing flashing operation methodologies.

Figures 8 and 9 provide late night hour volume information for North 27th Street and Highway 2, respectively. In calculating the time period to provide flashing operation, the most conservative approach was taken. This was achieved by using volume information from the intersection with the largest delay.

- North 27th Street: Along North 27th Street, between "P" Street and Kensington Drive, the intersection with the highest delay is 27th Street at Vine Street. This intersection operates with a PM Peak delay of 40.6 seconds per vehicle (LOS 'D'). As shown in Figure 8, twenty-five percent of the 27th Street PM Peak through movement volume at Vine Street provides the time period in which flashing operation could be implemented (11:30 p.m. to 5:00 a.m.).

- Highway 2: Along Highway 2, between Old Cheney Road and Van Dorn Street, the intersection with the highest delay is Highway 2 at 14th Street. This intersection operates with a PM Peak delay of 45.1 seconds per vehicle (LOS 'D'). As shown in Figure 9, twenty-five percent of the Highway 2 PM Peak through movements at 14th Street provides the time period in which flashing operation could be implemented (11:30 p.m. to 5:00 a.m.).

Figure 8:
North 27th Street between "P" Street and Kensington Drive
Flashing Operation

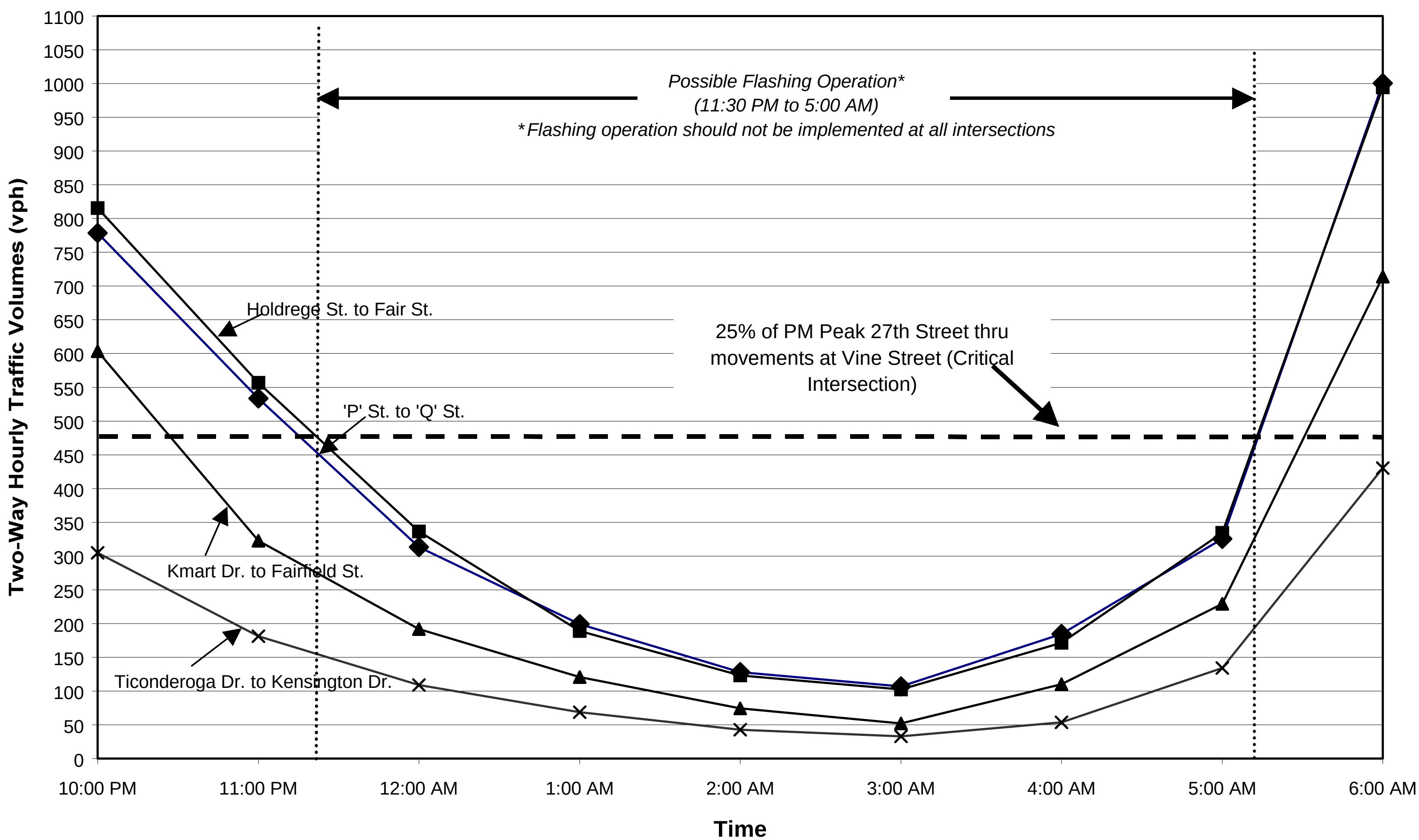
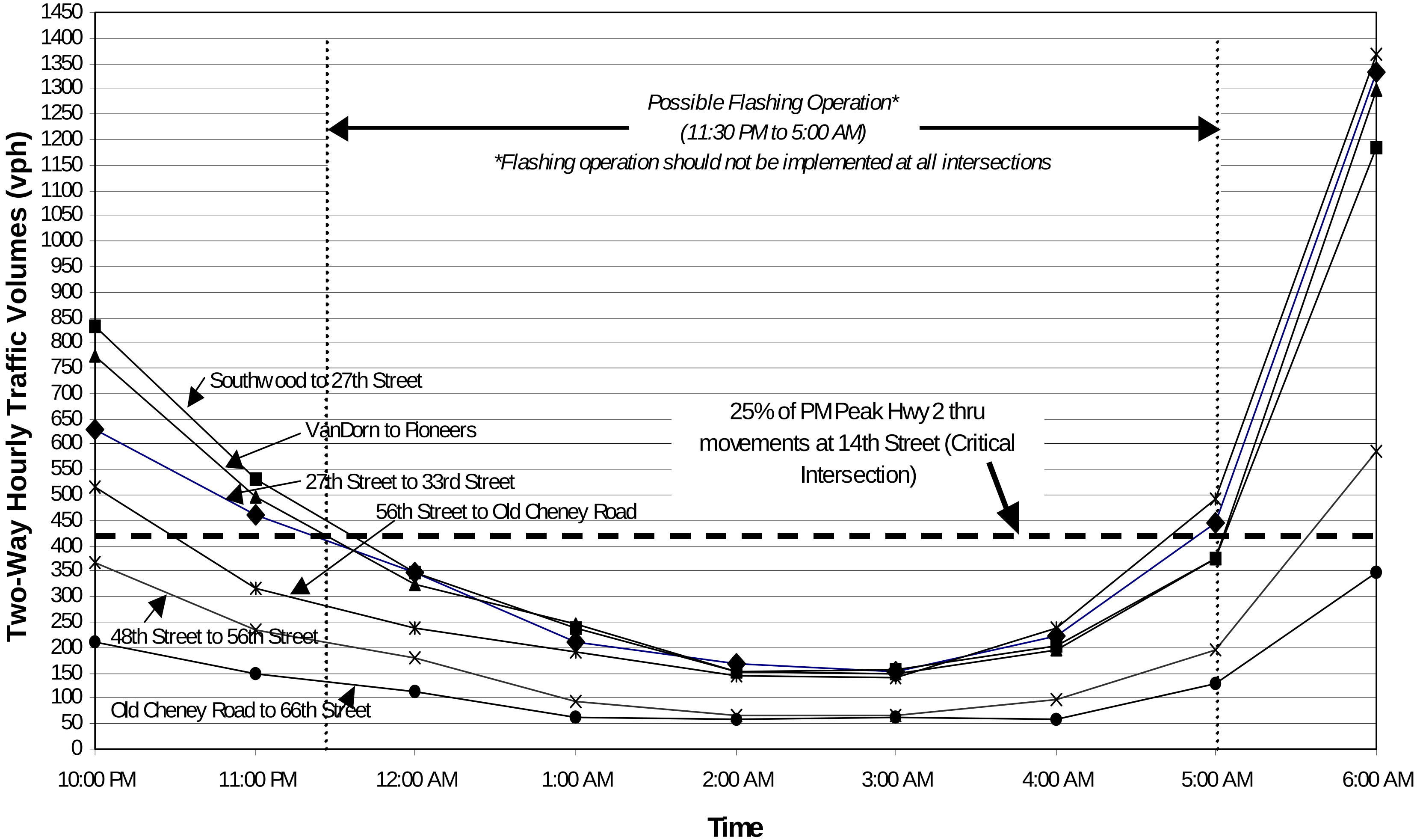


Figure 9:
Nebraska Highway 2 between Old Cheney Road and Van Dorn Street
Flashing Operation



The time period calculated for flashing operation along North 27th Street and Highway 2 are similar, 11:30 PM to 5:00 AM. It should be noted that this analysis only provides information on <u>when</u> flashing operation could be implemented. It does not determine whether or not flashing operation should be implemented. Figure 10 presents late night hour volume information at cross street intersections along 27th Street. A review of this figure also illustrates a large drop in traffic volumes along 27th Street's cross streets starting at 11:30 PM and a sudden increase after 5:00 AM. Figure 11 presents late night hour volume information at cross street intersections along Highway 2. A review of this figure also illustrates a large drop in traffic volumes along Highway 2 cross streets starting at 11:30 PM and a sudden increase after 5:00 AM. Appendix D presents more detailed volume information along 27th Street and Highway 2. A similar analysis is required for each corridor under study for possible flashing operation.

Free Operation

Similar to the flashing operation methodology, LOS 'B' was chosen as the threshold intersection operation level of service because it is defined by the HCM as "Stable operation / minimal delays: an occasional approach phase is fully utilized. Many drivers begin to feel somewhat restricted within platoons of vehicles".

Through examination of various major corridors in Lincoln, volumes that represent approximately 40% of the PM Peak period volumes at a critical intersection along a sub-system result in the reduction of delay at the intersection to high LOS 'B' (close to LOS 'C') operation. Similarly, due to the nature in which intersections operate under LOS 'B' or better and the arrival pattern of vehicles, developing platoons of vehicles for coordination is difficult. As a result, during these low volume periods, signal timing coordination would not result in much of a benefit. This intersection LOS was consistently achieved between the hours of 10:30 PM and 5:30 AM. In comparison to flashing operation and the basic definition and purpose of a signalized intersection, a signal in free operation has a higher capacity and can process more vehicles in a safe manner. The operation of an intersection at 40 percent of its PM Peak volume does result in turning movement volumes such that safety would not be compromised from the standpoint of traffic volume. It should be noted, however, that there are other considerations (i.e. vehicle composition and speeds) that should also be considered in developing free operation methodologies.

Figures 12 and 13 provide late night hour volume information for North 27th Street and Highway 2, respectively.

- North 27th Street: Along North 27th Street between "P" Street and Kensington Drive, the intersection with the highest delay is 27th Street at Vine Street. This intersection operates with a delay of 40.6 seconds per vehicle (LOS 'D') during the PM Peak. As shown in Figure 12, 40% of the 27th Street PM Peak through movement volume at Vine Street provides the time period in which "free" operation could be implemented (10:30 p.m. to 5:30 a.m.).

Figure 10:
Cross-Street Intersections along 27th Street

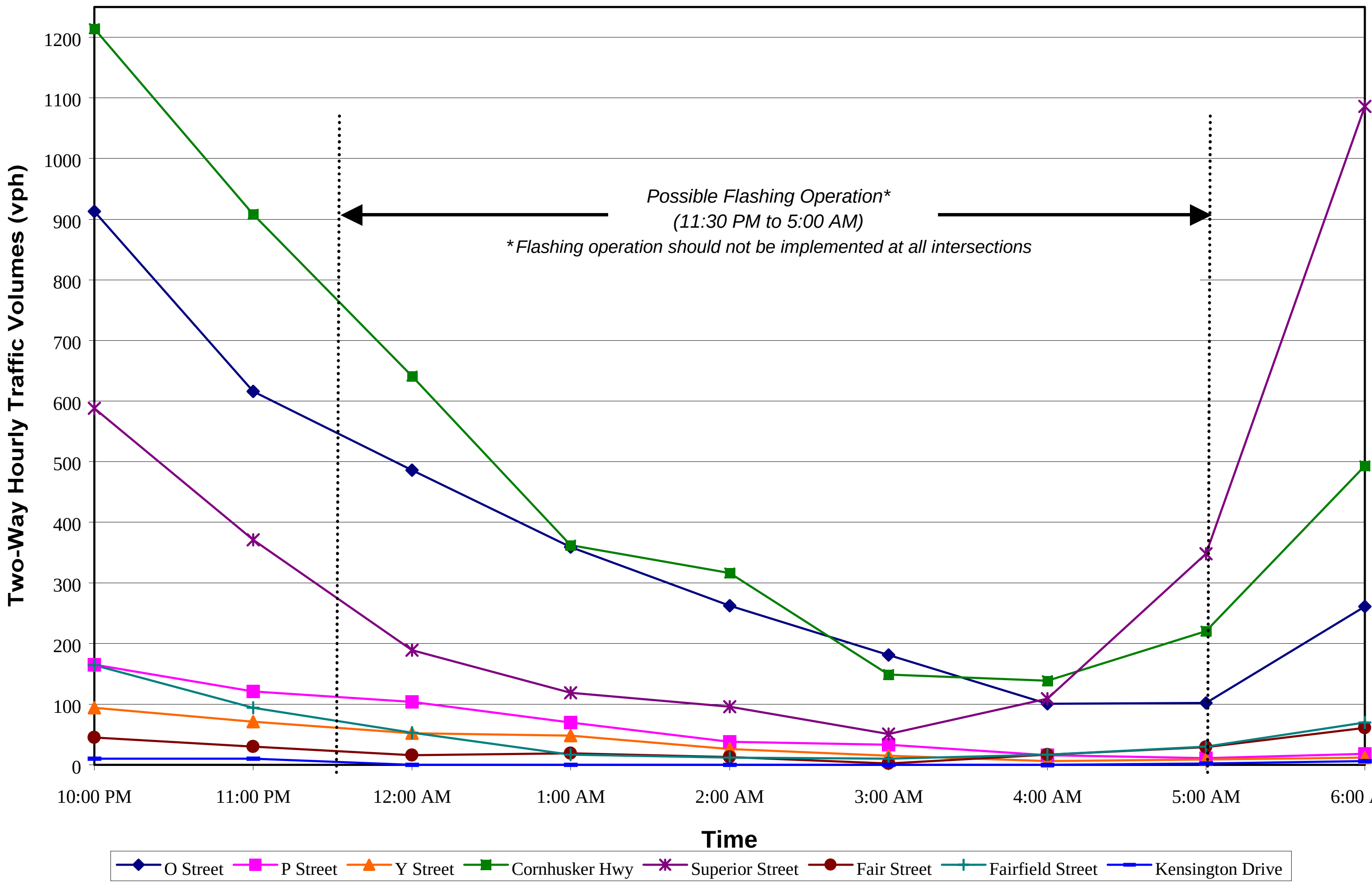


Figure 11:
Cross-Street Intersections along Nebraska Highway 2

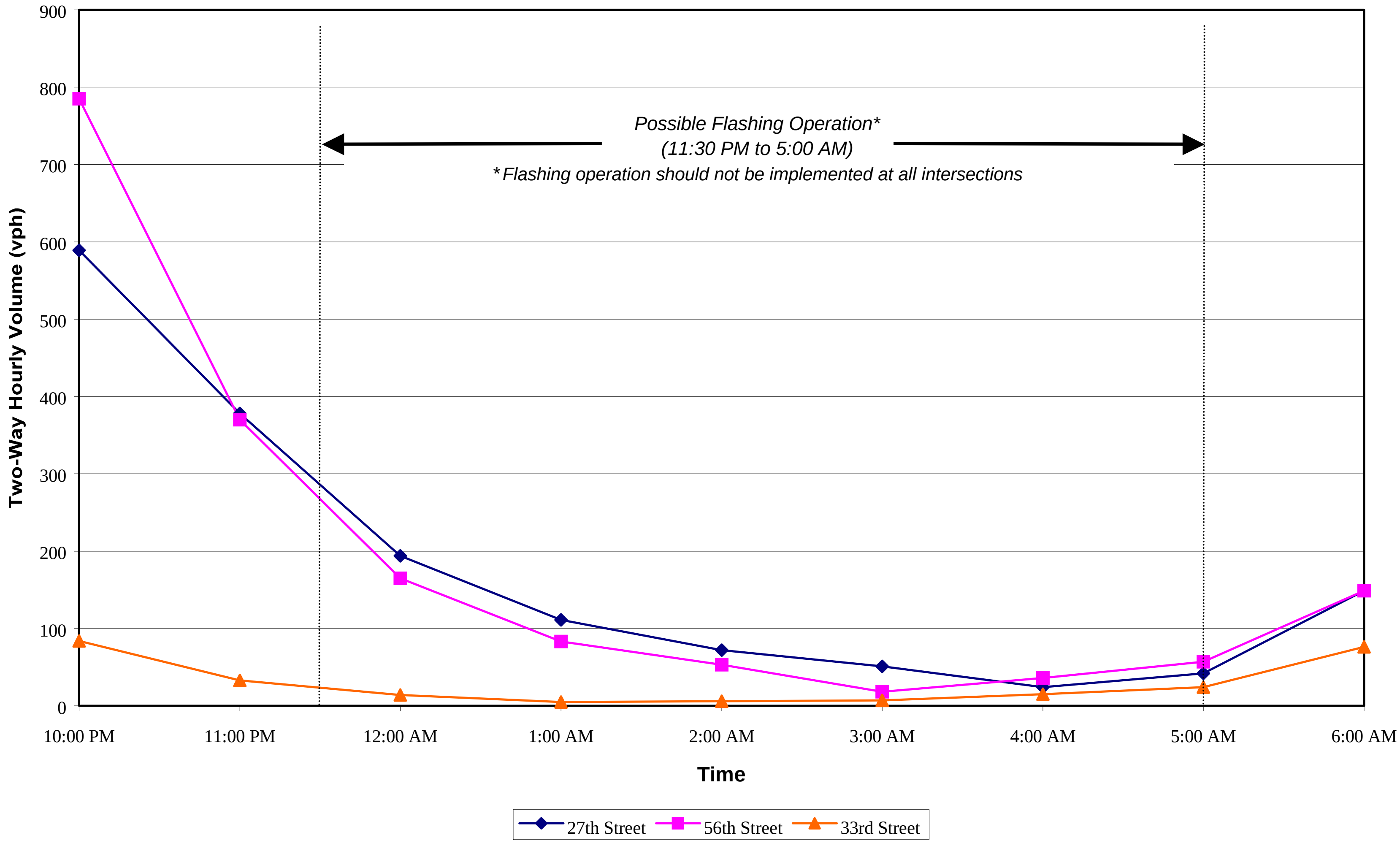


Figure 12:
North 27th Street between "P" Street and Kensington Drive
Free Operation

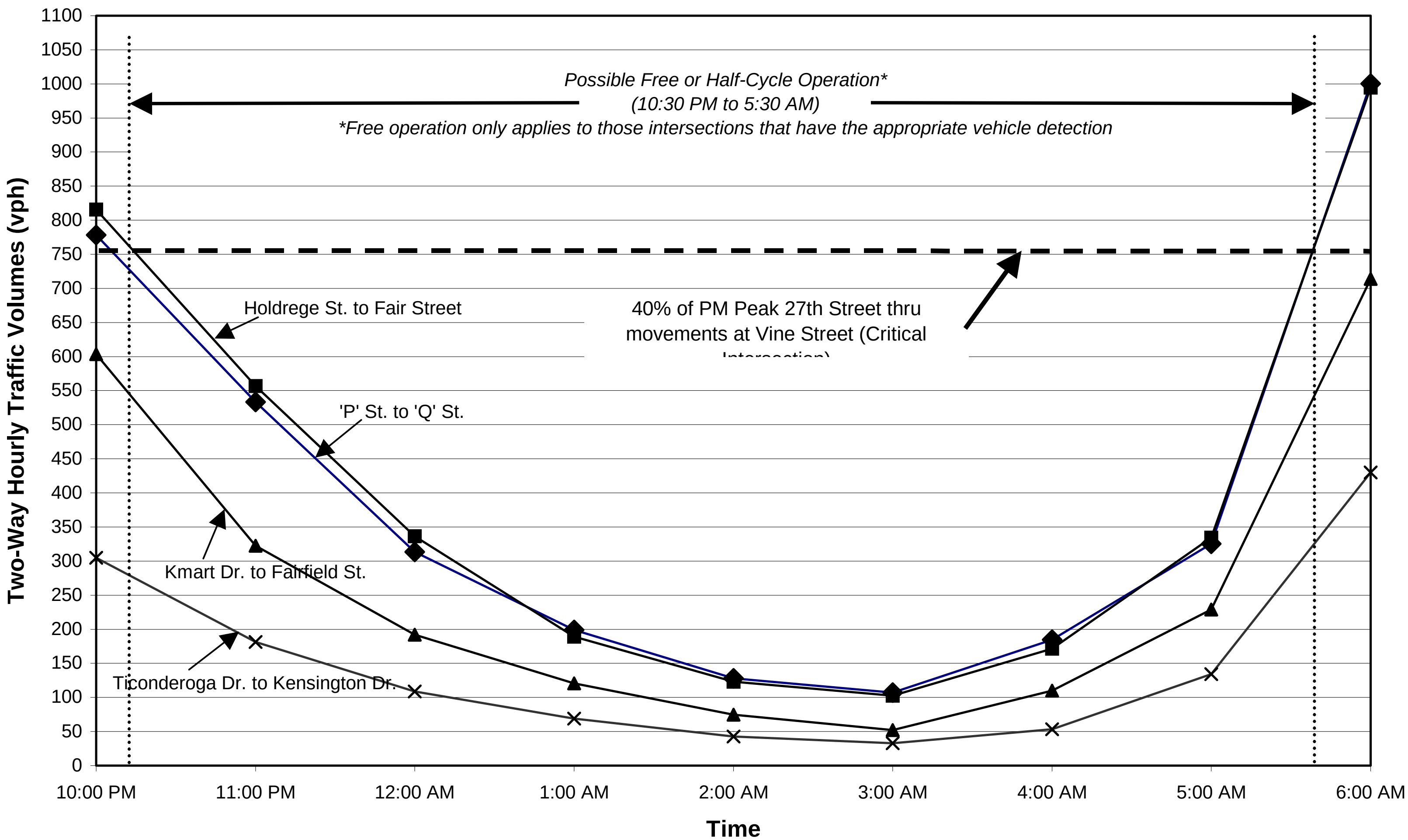
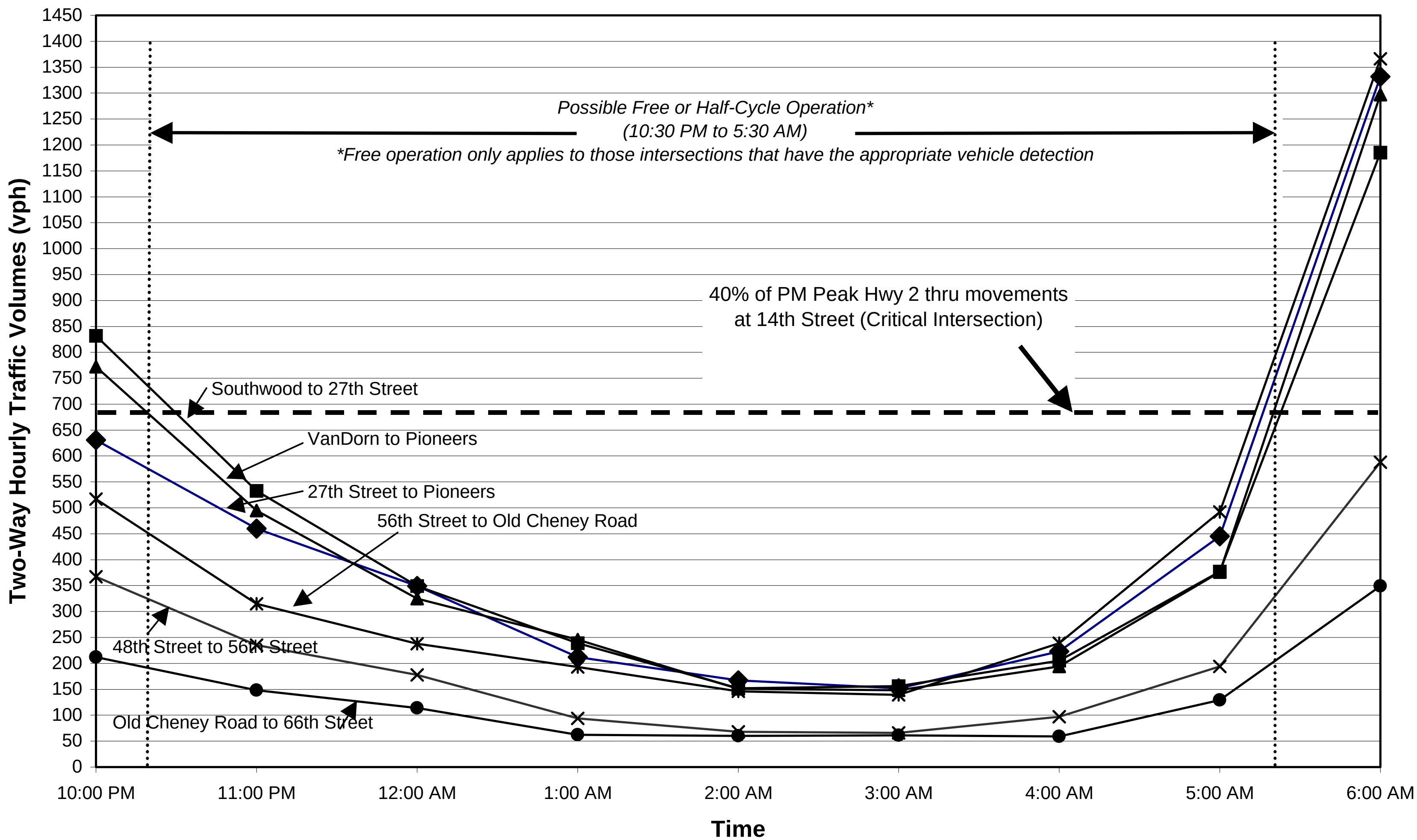


Figure 13:
Nebraska Highway 2 between Old Cheney Road and Van Dorn Street
Free Operation



- Highway 2: Along Highway 2 between Old Cheney Road and Van Dorn Street, the intersection with the highest delay is Highway 2 at 14th Street. This intersection operates with a PM Peak delay of 45.1 seconds per vehicle (LOS 'D'). As shown in Figure 13, 40 percent of the Highway 2 PM Peak through movement volume at 14th Street provides the time period in which "free" operation could be implemented (10:30 PM to 5:30 AM).

Appendix D provides late-night two-way hourly volume information along other corridors in the City of Lincoln.

5.5 Recommendations and Conclusions

In reviewing the published literature available, national standards, and familiarity with traffic conditions in Lincoln, Nebraska, the following recommendations are made for the operation of signals during the late night hours:

- Due to the possibility of increased accidents as a result of driver and pedestrian confusion, flashing operation is **not** recommended for the City of Lincoln, Nebraska during any time period. Flashing operation should only be reserved for intersection malfunction (flashing red for all approaches) or emergency vehicle signal pre-emption (if feasible). For these reasons, many cities and jurisdictions across the country have begun abandoning operating signalized intersections with flashing operation during late night hours.

- If the intersection is semi- or fully-actuated, the intersection should be set to operate with free operation.

- For fully-actuated intersections, also consider rest-in-red operation if advance detectors are available. With advance detectors and the proper arrangement (speed sensing), this operation can reduce night-time speeding. This operation should be tested along a specific sub-system first, prior to city-wide implementation.

- Pre-timed intersections without vehicle detection should operate at a reduced cycle length. The cycle length should be determined such that pedestrian minimums are met.

- Protected left-turn phases should lead in the signal operation during late night or low volume conditions.

- In order to consider the best overnight operation, each corridor or region (downtown or suburban area) should be analyzed separately, studying traffic volumes (vehicular and truck) and accident rates.

- In developing the time period to operate late night signal timing, it is recommended to develop a consistent schedule in each area or zone.